



ALMA MATER STUDIORUM | RESEARCH  
UNIVERSITÀ DI BOLOGNA | DIVISION



**FutureData4EU**

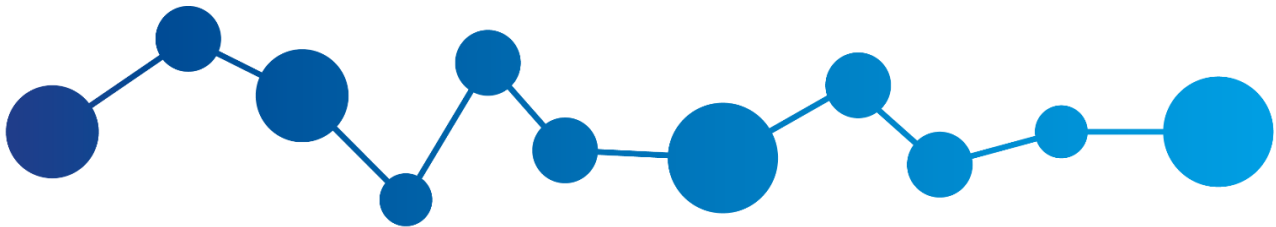
Training Future Big Data Experts for Europe

**ANNOUNCEMENT OF SELECTION FOR 53 PhD POSITIONS**

**FUNDED WITH RESEARCH FELLOWSHIPS**

**40th CYCLE – A.Y. 2024/2025**

**MARIE SKŁODOWSKA-CURIE ACTIONS – COFUND DOCTORAL PROGRAMME**



**FutureData4EU**

Training Future Big Data Experts for Europe

**Opening of the call for applications: 15 May 2024**

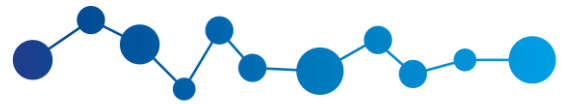
**Deadline for the submission of applications: 28 June 2024**

**at 2 pm CEST (Italian time)**



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## Introduction

The “FutureData4EU – Training Future Big Data Experts for Europe” project is funded under the “Marie Skłodowska-Curie Actions Co-funding of regional, national and international programmes – HORIZON-MSCA-2022-COFUND-01-01” call of Horizon Europe – the Framework Programme for Research and Innovation. FutureData4EU is a 60-month project that involves the launch of a doctoral programme with PhD positions at the University of Bologna and at other Emilia-Romagna universities acting as *Implementing Partners*, i.e. the Universities of Ferrara, of Modena and Reggio Emilia, of Parma, the Piacenza Campus of the Politecnico di Milano, and the Piacenza Campus of Università Cattolica del Sacro Cuore.

FutureData4EU aims to offer early stage researchers, i.e., not already in possession of a doctoral degree, an innovative training programme with a strongly international, inter-sectoral and inter-disciplinary approach, through transnational mobility and career development. FutureData4EU is open to researchers from all over the world. The project seeks to strengthen cooperation with the non-academic world, enabling young PhD students to develop their professional skills within local, regional and/or national socioeconomic ecosystems in the area of Big Data.

Big Data management, including through high-performance computing, is in fact regarded as the richness of the new knowledge economy. It provides unprecedented research and innovation opportunities across a number of applicative domains, from climate and geophysical simulations to health, from mobility and logistics to cultural heritage and multimedia, from digital change in production systems to new materials and financial analysis. Digital infrastructures, high-performance computing architecture, large-scale cluster architecture and ultra-wideband networks will experience significant innovation in the upcoming years.

70% of the Italian computing and storage capacity is currently located in Emilia-Romagna, thanks to the supercomputing facilities at CINECA (one of the European Large-Scale Facilities and founder of PRACE – Partnership for Advanced Computing in Europe), INFN (National Institute for Nuclear Physics), and the Leonardo supercomputer supported by the EuroHPC Joint Undertaking. CINECA and INFN are partners in the project, alongside Regione Emilia-Romagna, to create a lively research and innovation ecosystem, making Emilia-Romagna an authentic data valley and the ideal location to gain knowledge and skills in this domain.

This call for applications is published on the FutureData4EU website (<https://site.unibo.it/futuredata4eu/en>). Any additions, amendments or updates will also be published on the website. This announcement of selection is an official announcement to all intents and purposes.



## Art. 1. Programme description

### 1.1. Goals

The FutureData4EU PhD programme will train a new generation of researchers with inter-disciplinary and transferable skills, supporting their career and providing them with the knowledge necessary to work with academic and business organisations, thanks to a large network of Associated Partners involved in the project, from highly reputed businesses to high-level national and international research centres and infrastructures in the field of Big Data.

Within the project, candidates will have the possibility to apply for 47 different PhD programmes across the six Emilia-Romagna universities ([Annex 1 – FutureData4EU doctoral positions and research themes](#)), innovatively combining training, research and development of transferable skills in the area of Big Data. International talents will have the opportunity to learn by developing research and innovation projects across a wide range of thematic areas relevant to Big Data – health, culture, security, industry, aerospace, climate, energy, agriculture and environment.

### 1.2. Programme

This announcement of selection offers candidates from all over the world a total of 53 PhD positions for a duration of 36 months each, across a wide range of thematic areas relevant to Big Data. Candidates must meet the requirements for admission to third-cycle (doctoral) programmes, as well as the requirements stated in the “*Marie Skłodowska-Curie Actions Co-funding of regional, national and international programmes – HORIZON-MSCA-2022-COFUND-01-01*” call, as set out in this selection announcement ([Art. 2 Admission requirements](#)). The selection procedure will be open, transparent and merit-based ([Art. 4 Selection process](#)). The successful candidates will enter into a 36-month research fellowship contract.

47 PhD programmes make up the wide range of training opportunities available within FutureData4EU, with 53 PhD positions distributed among the universities of Emilia-Romagna, covering the following 7 Big Data thematic areas:

1. Health;
2. Culture, Creativity and Inclusive Society;
3. Civil Security for Society;

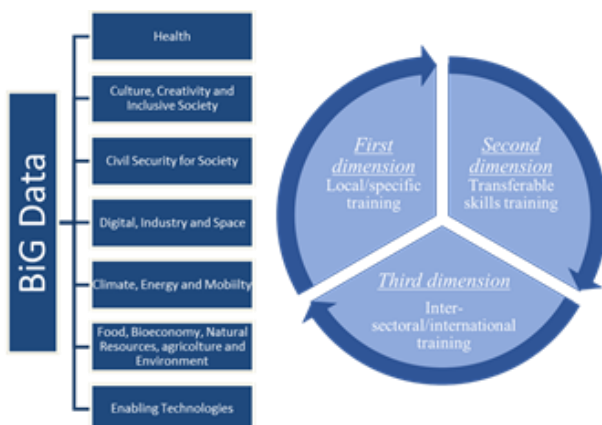


4. Digital, Industry and Space;
5. Climate, Energy and Mobility;
6. Food, Bioeconomy, Natural Resources, Agriculture and Environment;
7. Enabling Technologies

Each candidate will choose 1 thematic area, indicating – for information purposes only – their order of preference for each PhD position available in that area ([Annex 1 – FutureData4EU doctoral positions and research themes](#)). In order to assign available the PhD positions, the selection committee ([Art. 5 Evaluation Committee](#)), at its sole discretion, will assess each candidate’s suitability for one or more positions. In case of manifest or tacit withdrawal of a successful candidate, the position will be offered to the next suitable candidate on the ranking list ([Art. 6 Ranking lists](#)).

The training provided within the FutureData4EU project consists of three dimensions:

1. The first dimension of training concerns the disciplinary and multi-disciplinary domains of the research projects and the development of specific knowledge, methods and skills by attending courses, seminars and workshops.
2. The second dimension of training refers to transferable skills, including the ability to write and present scientific articles and reports at seminars, workshops and conferences; how to manage research data and open science; how to file a patent application and manage intellectual property; fundamentals of technology transfer and entrepreneurship; how to do scouting for research funds and how to prepare successful applications for funding. Transferable skills training will be provided both locally and during international and/or intersectoral secondments.



3. The third dimension of training covers international/inter-sectoral secondments. two secondments will be arranged – one at an international academic institution and one at a non-academic organisation – fostering inter-sectoral mobility.

## Art. 2. Admission requirements



On the deadline for applications, all candidates of every nationality must meet the following requirements, failing which they will be excluded:

- ✓ **Mobility.** Candidates must not have resided or carried out their main activity (work, studies, etc.) in Italy for more than 12 months in the 3 years immediately before the deadline of this call for applications, i.e., from June 29th, 2021 until June 28th, 2024. Compulsory national service and time spent as part of a procedure for obtaining refugee status under the Geneva Convention are not considered.
- ✓ **Qualifications.** Candidates must be in possession of a second-cycle academic qualification (e.g., two-year master's degree, degree of the previous degree programme system, equivalent Advanced Artistic and Musical Training – AFAM qualification).

Foreign qualifications must be recognised as equivalent to a second-cycle academic qualification and give access to PhD studies in the country of issuance.

Candidates who apply based on a qualification they obtained in a foreign (European Union/non-European Union) country without a document certifying its authenticity and equivalence to a second-cycle academic qualification (e.g., Diploma Supplement, *Dichiarazione di Valore*/Declaration of Value issued by the Italian diplomatic authority in the country where the qualification was obtained, proof of authenticity and comparability issued by organisations such as ENIC-NARIC), but in any case they must submit the aforementioned document, which is necessary for the declaration of authenticity and equivalence of the second-level degree obtained, by January 7, 2025, otherwise they will be excluded from the selection procedure.

- ✓ **Doctoral Candidate stage.** Candidates must not be already in possession of a doctoral degree.

The following candidates will not be admitted to the selection procedure:

- candidates who hold a tenured position at a university or institution referred to in Article 22, paragraph 1 of Law No. 240 of December 30, 2010 (hereinafter L. 240/2010);
- candidates who have a degree of kinship or affinity up to and including the fourth degree with a teacher of the department or organisational structure that offers the position and related contract, or with the Rector, the Director General or a member of the Board of Governors of the University



- candidates who had a Italian contract “*assegno di ricerca*” (research fellow) or Ricercatore a Tempo Determinato (fixed-term assistant professor) according to Articles 22 and 24 of Law 240/2010 with the University of Bologna or another state, non-state or virtual university, in Italy or abroad, or with an institution referred to in Article 22, paragraph 1 of Law 240/2010, for a total period that, when added to the duration of the contract for which they are applying for, exceeds 12 years, including on a non-continuous basis. Periods on maternity/paternity or long-term medical leave in accordance with the legislation in force are not taken into account when calculating the abovementioned duration.

## Art. 3. Application

### 3.1. Application procedure

Applications may only be submitted through the dedicated procedure available at <https://studenti.unibo.it> (online platform Studenti Online).

The application deadline is June 28th, 2024, at 2:00 PM (CEST, Italian time).

In order to be accepted, the application must be:

- Sent before the deadline via the online submission procedure by accessing at [Studenti Online](#). All annexes must be uploaded in pdf format.
- Accompanied by all the required documentation ([3.2 Documents to be attached to the application](#)).

Failing to meet any of the requirements of [Art. 2 Admission requirements](#) will result in the exclusion of the candidate, at any time during the selection procedure or upon signing the contract.

Applications submitted in any way other than the above will not be considered.

This selection announcement, its annexes and all documents relevant to the application are available on the FutureData4EU website (<https://site.unibo.it/futuredata4eu/en>).

### 3.2. Documents to be attached to the application

Candidates will be required to attach the following documents to their online application:





	DOCUMENTS REQUIRED	DESCRIPTION
a)	<b>Valid photo ID document</b>	Scanned image of both sides.
b)	<p><b>Proof of achievement of each second-cycle academic qualification obtained, detailing:</b></p> <ol style="list-style-type: none"> <li>1. University that issued the qualification</li> <li>2. Type of degree (two-year master's degree, single-cycle degree, degree of the previous degree programme system, etc.)</li> <li>3. Name of degree programme</li> <li>4. Degree programme class (only for Italian qualifications)</li> <li>5. Date of qualification</li> <li>6. Final grade</li> <li>7. List of exams and marks, indicating the number of University credits (CFU), if in use within the university system that issued the qualification.</li> </ol>	<p>Type of proof, for qualifications issued by:</p> <ol style="list-style-type: none"> <li><b>1. Italian state universities:</b> Dated and signed self-certification of bachelor's degree and master's degree or degree of the previous degree programme system.</li> <li><b>2. EU/non-EU universities:</b> <ul style="list-style-type: none"> <li>- Transcript of records of the second-cycle academic qualification (in English);</li> <li>- If already available, document to certify the authenticity and equivalence of the qualification (e.g. Diploma Supplement, Dichiarazione di Valore/Declaration of Value issued by the Italian diplomatic authority in the country where the qualification was obtained, proof of authenticity and comparability issued by organisations such as ENIC-NARIC) (in English). Please be aware that failing to submit the aforesaid document by January 7th, 2025 at the latest implies exclusion from the selection procedure.</li> </ul> </li> <li><b>3. Italian private universities:</b> as an alternative to the certificate, a self-certification complete with all required information or the Diploma Supplement may be attached.</li> </ol>
c)	<b>Document stating the selected thematic area and the order of preference for each available PhD position within the area.</b>	<p>Pdf document generated through the Form On Line (FOL) system, available at <a href="https://fol.unibo.it/futuredata4eu">https://fol.unibo.it/futuredata4eu</a>.</p>
d)	<b>Curriculum Vitae in English</b>	Please use the CV template available on the project

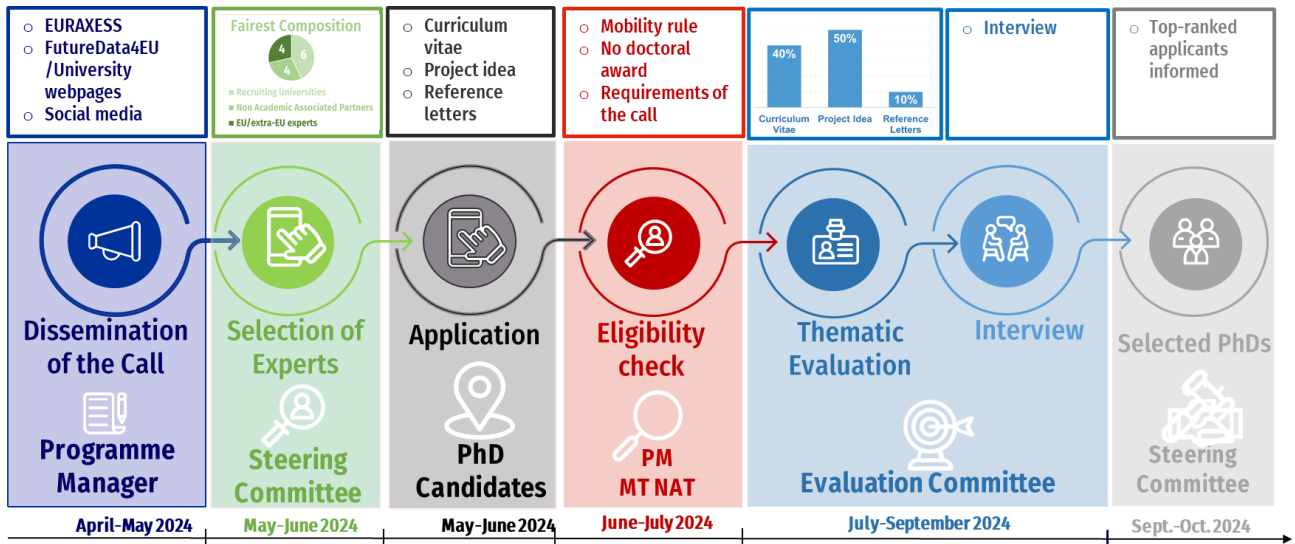
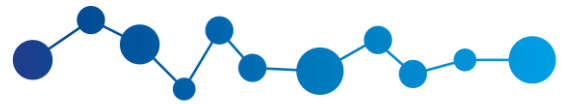


		website.
<b>e)</b>	<b>Research project</b>	<p>To be drafted:</p> <ul style="list-style-type: none"> <li>- in English;</li> <li>- using the template available on the FutureData4EU website (<a href="https://site.unibo.it/futuredata4eu/en">https://site.unibo.it/futuredata4eu/en</a>);</li> <li>- maximum length of three (3) pages excluding charts and images (pages in excess will be discarded).</li> </ul> <p>The research project must include: project title; research theme selected from among those available; project idea, goals, proposed research methodology; relevance of the project to the candidate's competencies, also in relation to the position for which the application is submitted.</p>
<b>f)</b>	<b>Max. 3 reference letters in English</b>	Reference letters will be subject to evaluation.
<b>g)</b>	<b>Other relevant documents</b>	Additional documents that the candidate deems useful for the evaluation, in relation to the available positions ( <a href="#">Annex 1 – FutureData4EU doctoral positions and research themes</a> ).
<b>h)</b>	<p><i>For candidates who wish to request adaptations to be made for the entrance test</i></p> <p><b>Request for adaptation form and required medical certificate</b></p>	For further information on the adaptations and documentation to be attached, see the section <a href="#">4.3 Candidates with disabilities or specific learning disorders (SLD)</a> of this call.

## Art. 4. Selection process

### 4.1. Selection steps

The indicative timetable for the selection process is presented below.



Any delays in or notices concerning the overall process will be published on the FutureData4EU website (<https://site.unibo.it/futuredata4eu/en>).

Consistently with the principles and requirements of the European Charter for Researchers, the Code of Conduct for the Recruitment of Researchers and the Human Resources Strategy for Researchers – HRS4R, the selection process will respect the principles of fairness and equality, avoiding any form of discrimination based on gender, age, ethnicity, national or social origin, religion or belief, sexual orientation, language, disability, political opinion, social or economic status or nationality, in accordance with the principles expressed by all involved recruiting universities.

The entire selection process consists of four steps. The results for each step will be anonymised and published on the FutureData4EU website as soon as the process is completed. The candidates will be informed of the publication of the results by email from [cofund@unibo.it](mailto:cofund@unibo.it) exclusively to their University email address [name.surname@studio.unibo.it](mailto:name.surname@studio.unibo.it), assigned upon registering on the Studenti Online website, before filling out the application.

- ✓ **STEP 1) Eligibility check.** The eligibility check will be performed by the Programme Manager (PM) together with the Project Management Team (MT) and the Network Administrative Team (NAT). Candidates may be asked to provide further clarifications or to integrate provided documents at this stage, through the institutional email address [nome.cognome@studio.unibo.it](mailto:nome.cognome@studio.unibo.it) assigned to each candidate. The results of this phase will be published starting from July 8th, 2024.



- ✓ **STEP 2) Document evaluation.** An Evaluation Committee will be set up, comprised of seven Panels, one for each thematic area. Each Panel will be made up of 14 panellists ([Art. 5 Evaluation Committee](#)). Initially, each panellist will evaluate the applications independently and remotely, assigning a score to each candidate according to specific criteria ([4.4 Evaluation criteria](#)). The Panel will then meet in person or online to discuss each evaluation and reach a unanimous score.  
For each thematic area, based on the assigned score assigned, a shortlist of the candidates admitted to Step 3 will be prepared, anonymised and published on the FutureData4EU website, starting from July 17th, 2024. Candidates admitted to Step 3 will be invited to an interview through the aforementioned institutional University email address, while those who did not pass to the interview will be informed of the outcome of Step 2. The interviews will be scheduled starting from July 18th, 2024.
- ✓ **STEP 3) Interview.** All interviews will be conducted by the single Panels in English and remotely via the Microsoft Teams platform. Each interview will last approximately 30 minutes. At the beginning of the interview, each candidate must present the original identification document attached to the admission application. Each candidate will be assigned a score according to the specified evaluation criteria ([4.4 Evaluation criteria](#)) and a suitability evaluation for one or more advertised position, at the sole discretion of the Panel. The results of Phase 3 will be anonymously published on the FutureData4EU website (<https://site.unibo.it/futuredata4eu/en>) starting from September 10th, 2024. Notification of the publication will be sent to the involved candidates through the aforementioned institutional email address.
- ✓ **STEP 4) Final decision and ranking list.** The Evaluation Committee, in agreement with the NAT, will prepare a final ranking list for each thematic area based on the score for Steps 2 and 3, indicating the suitability status assigned after Step 3 and proposing the assignment of winners to individual positions. The 7 final ranking lists will be subject to approval by the FutureData4EU Steering Committee. The final rankings will be anonymously published on the FutureData4EU website (<https://site.unibo.it/futuredata4eu/en>) starting from September 24, 2024. Notification of the publication will be sent to the involved candidates through the aforementioned institutional email address. Candidates who have been assigned a position will be informed via the institutional email address about the subsequent steps related to contracting and enrollment, managed by the respective universities of the region. In case of withdrawal, the position will be assigned in order of ranking to the next eligible candidate for the same position ([Art. 6 Ranking lists](#)).



## 4.2. Redress procedure

After publication of the final ranking lists, candidates may file a judicial appeal (within 60 days) or an extraordinary appeal (within 120 days), as provided for by the regulations in force, if they believe that there have been irregularities in the evaluation process that have affected the final decision. Redresses may only concern procedural aspects and/or clerical errors, but not the evaluating experts' opinion on the quality of an application.

## 4.3. Candidates with disabilities or specific learning disorders (SLD)

Candidates who wish to request adaptations to be made for the entrance test must do so by the deadline for the submission of applications.

Please note that, since the evaluation only concerns the requirements to apply, and no written test is foreseen, but only an oral interview, the request may only be submitted if adaptations are necessary for the interview (Step 3).

Adaptations may comprise:

- Additional time for the candidate to think and organise their answers;
- Questions in writing during the interview for candidates with hearing disabilities;
- Other adaptations depending on the specific certified difficulties or needs related to the candidate's health (please specify the adaptations required).

The list of available adaptations is included in the Request for adaptation form, as specified below. If the adaptation requested cannot be guaranteed for organisational reasons and/or due to mandatory instructions, an alternative, equivalent measure will be implemented.

The procedure for requesting adaptations is as follows:

- Access *Studenti Online* and go to the application for selection;
- Download the Request for adaptation form (available in .pdf format);
- Fill in and upload, in the appropriate section, the Request for adaptation form (in .pdf format);
- Upload the necessary specialist documentation in the appropriate section, as specifically requested in the Request for adaptation form (in .pdf format).

Please do not upload any unrelated documentation to this section.



Candidates with disabilities or SLD residing in foreign countries who intend to request adaptations must submit a legalised (or apostilled, where provided) certification confirming their disability or SLD, issued in their country of residence and accompanied by an official translation into Italian or English.

The specialist documentation will be examined by the competent offices to make sure that it certifies a disability or specific learning disorder recognised by the legislation of Italy or the candidate's country of residence.

The documentation will be examined by the Service for Students with Disabilities and SLD to make sure that the request for adaptations is consistent with the documentation submitted. If the documentation is incomplete or hard to read, supplementary details will be requested, via the University email account [name.surname@studio.unibo.it](mailto:name.surname@studio.unibo.it), which must be submitted by the final deadlines specified in the message.

It will not be possible to make the adaptations requested by candidates who fail to submit their request by the deadline above or fail to send the required supplementary documentation by the deadline indicated by the Service for Students with Disabilities and SLD.

Any adaptations granted will be notified via e-mail from [cofund@unibo.it](mailto:cofund@unibo.it) to the University email address [name.surname@studio.unibo.it](mailto:name.surname@studio.unibo.it).

Clarifications strictly concerning the procedures for requesting adaptations may be obtained by contacting the Service for Students with Disabilities and SLD via email to [ases.adattamentiammissione@unibo.it](mailto:ases.adattamentiammissione@unibo.it).

Any adaptations granted will be notified via e-mail from [cofund@unibo.it](mailto:cofund@unibo.it) to the University email address [name.surname@studio.unibo.it](mailto:name.surname@studio.unibo.it).

Clarifications strictly concerning the procedures for requesting adaptations may be obtained by contacting the Service for Students with Disabilities and SLD via email to [ases.adattamentiammissione@unibo.it](mailto:ases.adattamentiammissione@unibo.it).

#### 4.4. Evaluation criteria

Applications will be evaluated based on the following criteria.

**STEP 1: Eligibility check, carried out by the NAT**

*Eligibility threshold:* both criteria must be met. Each criterion will receive a positive/negative evaluation (pass/fail).



Eligibility of candidates	Compliance with admission requirements ( <a href="#">Art. 2 Admission requirements</a> )	PASS/FAIL
Eligibility of applications	Compliance with application procedures ( <a href="#">Art. 3 Application</a> ).	PASS/FAIL
<p><b>STEP 2: Document evaluation, carried out by the Evaluation Committee</b></p> <p><i>In Step 2, each candidate will receive a score 0-100.</i></p> <p><i>Threshold for admission to Step 3: 70/100.</i></p> <p>Justified career interruptions (e.g. maternity/paternity leave, military service) will not be penalised.</p>		
CV evaluation (score 0-40)	<p><i>The use of the FutureData4EU CV template is recommended.</i></p> <p>The following aspects will be taken in consideration: University education, English proficiency, experience and achievements (e.g. research experience, awards/recognitions, international mobility experience), contribution to intellectual property (e.g. registered patents), work experience, relevance to the selected thematic area.</p>	max. 40 points
Research project evaluation (score 0-50)	<p><i>The use of the FutureData4EU model is mandatory.</i></p> <p>The following aspects will be taken in consideration: significance and relevance of the research project idea to the selected thematic area and available PhD positions, clarity in the description of the objectives, validity of the proposed methodology, coherence of the competencies declared with the research project idea.</p>	max. 50 points



Reference letter evaluation (score 0-10)	The relevance and appropriateness of the submitted letters of reference will be evaluated.	max. 10 points
<p><b>STEP 3: Interview conducted by the Evaluation Committee</b></p> <p><i>In Step 3, each candidate will receive a score 0-100.</i></p> <p><i>Threshold for admission to Step 4: 70/100</i></p> <p>All interviews will be conducted online via Microsoft Teams in English.</p>		
Excellence of the candidate and suitability for the positions available (score 0-100)	Soundness of the candidate’s cultural and scientific background, ability to argue their research project, motivation and personal career prospects will be evaluated.	max. 100 points
<p><b>STEP 4: Final ranking list prepared by the Evaluation Committee</b></p> <p>The final ranking list will be prepared by adding together the scores for Steps 2 and 3 and will include a list of candidates who scored at least 140/200. The ranking list will also indicate each candidate’s suitability status with respect to the available positions.</p>		

## Art. 5. Evaluation Committee

### 5.1. Evaluation Committee and Panels

An Evaluation Committee will be set up, made up of seven Panels. Each Panel will be comprised of at least 14 panellists, selected to ensure:

- Fair balance between internal and external panellists: 5 to 7 experts will come from the Emilia-Romagna universities involved in the FutureData4EU programme;
- European dimension: 4 to 5 experts will be based in a country other than Italy;
- Intersectoral presence: 3 to 4 experts will be selected from among the FutureData4EU non-academic associated partners.

Each candidate will be evaluated by at least 7 members: 3 panellists from the host universities, 2 international experts and 2 panellists from the non-academic associated partners. Subject to the availability of the panellists, an attempt will be made to ensure a gender balance.





## 5.2. Appointment of the experts: confidentiality and no conflict of interest

All expert evaluators involved in the evaluation process will be required to sign a confidentiality agreement regarding information and documents. The experts will also have to guarantee the absence of any conflict of interest.

### Art. 6. Ranking lists

The final ranking list for each thematic area will be prepared by the Evaluation Committee ([5.1 Evaluation Committee and Panels](#)) by adding together the scores for Steps 2 and 3.

In the event that two or more candidates obtain the same score, the ranking order will be determined by considering, in this order:

- Whether the candidate is a beneficiary of international protection (with refugee or subsidiary protection status);
- The least represented gender among the successful candidates in the thematic area, without taking withdrawals into account;
- Which candidate is the youngest.

At its sole discretion, the Evaluation Committee will give an opinion on each candidate's suitability for the PhD positions available. Each candidate may be suitable for one or more positions.

Each position will be assigned at the sole discretion of the Evaluation Committee to a candidate suitable for that position on the merit ranking list, based on the score obtained and on the candidate's suitability status for the position in question.

Each successful candidate will be admitted to the corresponding PhD programme at the university that offered the position and will be asked to sign the research fellowship contract (*Assegno di ricerca*) effective from March 1st, 2025.

It will be possible to proceed down the ranking list due to the following:

- manifest withdrawal from the position through an email sent from the institutional email address ([nome.cognome@studio.unibo.it](mailto:nome.cognome@studio.unibo.it)) generated at the time of submitting the admission application to the address [cofund@unibo.it](mailto:cofund@unibo.it);



- tacit withdrawal from the position, by not confirming acceptance of the position within the specified deadlines, not signing the contract, or not enrolling in the doctoral programme;
- failure to submit the necessary documentation for contracting and enrolment within the specified deadlines.

In such cases, the vacant position will be offered to the next eligible candidate in the ranking list for that specific thematic area.

Please note that January 7th, 2025 is the final deadline for submitting the documentation referred to in Article [3.2 Documents to be attached to the application](#), failing which the application will be excluded from the selection procedure.

It will not be possible to proceed down in the ranking list beyond February 11th, 2025.

## Art. 7. Contract signature and enrollment

Successful candidates will be offered a contract for *Assegno di ricerca* and be enrolled in the PhD programme at the recruiting university, according to the specific indications and deadlines that will be communicated.

## Art. 8. Contract and salary

### 8.1. Contract and working conditions

The university involved in FutureData4EU as an Implementing Partner who offered the position will enter into a three-year (36-month) employment contract with the corresponding successful candidate. The contract will be in the form of a Research Fellowship (*Assegno di ricerca* pursuant to Art. 22 of L. 240/2010), to be signed by the successful candidate and the Head of the hosting Department. It will specify the working conditions of the PhD student, their obligations under FutureData4EU and the regulations in force at the host university. The signing of the contract implies an exclusive and full-time commitment. The Research Fellowship is exempt from tax, but includes compulsory social security contributions (pension, work accident insurance, sickness, maternity/paternity, adoption and foster care leave).

During periods of absence due to leave or accident as mentioned above, subject to appropriate notification by the research fellow, the activity covered by the research fellowship will be suspended. The employment relationship will continue for the remaining period, resuming when the cause of suspension ends.



During periods of mandatory maternity/paternity leave, the allowance paid by INPS will be supplemented up to the full amount of the research fellow, as divided into the appropriate number of monthly instalments.

The contract may also be suspended in the event of parental leave, sickness or other extended periods of absence that make it objectively impossible to carry out the activities. In such cases of suspension, the contract will be extended for the duration of the suspension.

## 8.2. Salary

The annual salary paid to researchers is of €27,238.83 (gross salary excluding employer's contributions to tax and social security). This annual amount consists of a living allowance and a mobility allowance, which covers mobility expenses (e.g. relocation, travel expenses).

Researchers with dependents at the time of recruitment, or who acquire dependents at any time during the course of the project, will be entitled to a family allowance. This is reserved for those who (i) are married or (ii) are in a relationship equivalent to marriage recognised by the law of the country in which that relationship was formalised, or (iii) have dependent children who are effectively supported by the candidate.

The research project carried out by the candidate will receive financial support for research, training and networking costs, which can be used to purchase research materials and equipment and cover publication costs, travel expenses (e.g. to attend conferences/training courses, networking activities) and external services. Funding will be managed by the host Department and subject to the Supervisor's approval.

## Art. 9. Start of the doctoral programmes and tuition fees

Successful candidates will enrol in the FutureData4EU PhD programmes starting in the 2024/2025 academic year. The FutureData4EU PhD programme will start on March 1, 2025.

FutureData4EU doctoral students are exempt from paying any tuition fees for doctoral programmes. However, they are required to cover registration fees, which include the regional tax for the right to education, stamp duty, and insurance. These fees will be subsequently reimbursed.



## Art. 10. Obligations of FutureData4EU PhD students

### 10.1. Activities of FutureData4EU PhD students

The FutureData4EU PhD students are required to carry out the research project that will be assigned to them, which will not necessarily be the one they submitted upon applying for the PhD position. The research project to be carried out during the PhD programme will be approved by the Academic Board of the PhD programme in which they will be duly enrolled. The research project will be part of the researcher's career development plan, to be agreed with the Supervisor together with the planned training activities. Each year, following the assessment of the activity carried out by the FutureData4EU PhD student, the competent Academic Board of the PhD programme will decide whether to admit the FutureData4EU PhD student to the following year. By reasoned decision, the competent body may recommend that the PhD student be excluded from the programme.

### 10.2. Secondments

In order to ensure that the FutureData4EU PhD students receive the most innovative and cutting-edge training and fully benefit from the opportunities offered to them, 2 secondments are recommended: one of 6-8 months at an academic institution in Europe, and one of 4-6 months at a non-academic (inter-sectoral) organisation. The total duration of secondments may not exceed 12 months.

### 10.3. Publications

All scientific publications resulting from research funded under this call must be open access. Furthermore, in all publications and dissemination material (e.g. posters presented at conferences), the FutureData4EU PhD students must mention the funding programme by including the European Union flag followed by the wording: *"Co-funded by the European Union"* and the disclaimer: *"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or Research Executive Agency. Neither the European Union nor the granting authority can be held responsible for them"*.



## Art. 11. Award of the qualification

The award of the PhD degree is subject to full compliance with the regulations for PhD programmes, in force at the respective host universities.

The final exam will consist in the discussion of the candidate's thesis.

## Art. 12. Ownership of results and confidentiality

The intellectual and industrial property rights over any results achieved by the PhD student, including but not limited to software, industrial inventions (patentable or otherwise), know-how, models, data and data collections, are governed in accordance with the law in force, the recruiting university's regulations, and any agreements executed with other universities, firms or institutions involved.

The FutureData4EU PhD students must promptly inform their Supervisor of any results achieved and agree not to disclose or use them without the authorisation of the recruiting university.

The FutureData4EU PhD students are also required to sign a confidentiality and intellectual property right acknowledgement agreement in relation to any confidential information, data and documents that may come to their attention in the course of their activity at and/or on behalf of the recruiting university.

In any case, the PhD students are permitted to undertake standard publication activities foreseen in their training programme, although this must be scheduled in a manner that allows protection of research results.

## Art. 13. Ethical principles

Research and innovation activities must comply with national, international and EU ethical principles and standards. Special attention must be paid to the principle of proportionality, the right to privacy, the right to personal data protection, the right to a person's physical and mental integrity, the right to non-discrimination and the need to ensure high levels of protection of human health. Research and innovation activities must focus on civil applications only.

## Art. 14. Processing of personal data

Pursuant to Article 13 of Regulation (EU) 2016/679, the personal data provided by the candidates in the application or however obtained for that purpose by the universities will be processed for the purpose of conducting the selection and managing any related activities and tasks. The data will be processed by the



persons responsible for the selection, including the Evaluation Committee, in the manner, with the timing and to the extent required to achieve the aforementioned purposes, including disclosure to third parties for the purposes specified in this call, if needed. The legal basis for the data processing is Article 6, paragraphs 1(c) (processing for compliance with a legal obligation) and 1(e) (processing for the performance of a task carried out in the public interest) and Article 9, paragraph 2(g) (processing for reasons of substantial public interest) of Regulation (EU) 2016/679.

The joint controllers for the purposes of this evaluation and selection of PhD candidates are:

- Alma Mater Studiorum – Università di Bologna (registered office: via Zamboni 33, 40126 – Bologna, Italy). The Data Protection Officer's contact email: [dpo@unibo.it](mailto:dpo@unibo.it); certified email: [scriviunibo@pec.unibo.it](mailto:scriviunibo@pec.unibo.it);
- Università Cattolica del Sacro Cuore – Campus di Piacenza e Cremona (registered office: Largo Gemelli n. 1, 20123 – Milano, Italia; The Data Protection Officer's contact email: [dpo@unicatt.it](mailto:dpo@unicatt.it); PEC: [direzione.sede-pc@pec.ucsc.it](mailto:direzione.sede-pc@pec.ucsc.it);
- Università di Ferrara (registered office: via Ludovico Ariosto 35, 44121 – Ferrara, Italy. The Data Protection Officer's contact email: [privacy@unife.it](mailto:privacy@unife.it); [dpo-team@lepida.it](mailto:dpo-team@lepida.it); certified email: [ateneo@pec.unife.it](mailto:ateneo@pec.unife.it));
- Università degli studi di Modena e Reggio Emilia (registered office: via Università 4, 41121 – Modena, Italy; The Data Protection Officer's contact email: [dpo@unimore.it](mailto:dpo@unimore.it); certified email: [dpo@pec.unimore.it](mailto:dpo@pec.unimore.it);
- Università di Parma (registered office: via Università 12, 43121 – Parma, Italy; The Data Protection Officer's contact email: [dpo@unipr.it](mailto:dpo@unipr.it); certified email: [dpo@pec.unipr.it](mailto:dpo@pec.unipr.it));
- Politecnico di Milano (registered office: Piazza Leonardo Da Vinci 32, 20133 – Milan, Italy; The Data Protection Officer's contact email: [privacy@polimi.it](mailto:privacy@polimi.it); certified email: [pecateneo@cert.polimi.it](mailto:pecateneo@cert.polimi.it)).

Each university, acting as an independent controller for the subsequent steps of the selection process, will store and use any personal data and contact details provided by the PhD students also after completion of the selection procedures for operational, administrative, accounting and/or other purposes in connection with the management of institutional and project-related activities as well in order to comply with the law, as well as to notify them of any opportunities (scholarships, awards, etc.).

The personal data for the subsequent contract signing and enrolment procedures will be collected and processed by each university as an independent controller, in accordance with the aforementioned



regulations and in compliance with the privacy policy statement available on the institutional website of each university. They may be shared with Alma Mater Studiorum - University of Bologna for project-related reporting and auditing purposes.

In any case, the provision of personal data is essential in order to participate in the selection and for the subsequent contract signing and enrolment procedures. Failure to provide such data will make it impossible to participate in the selection process and be admitted to the PhD programmes.

The candidates have the right to access the personal data they have provided to participate in the competitive selection and for contract signing and enrolment purposes, to request and obtain the rectification, erasure or restriction on processing, as well as to object to the processing of their data by sending a request to the competent offices of the recruiting university.

Data subjects who believe that their personal data have been processed in violation of the requirements of the aforementioned EU Regulation may file a complaint with the Data Protection Authority or with the competent court.

## Art. 15. Final provisions

For anything not provided for in this call, please refer to the Regulations governing PhD programmes of the recruiting universities, to Ministerial Decrees 226/2021 and 301/2022, to Article 22 of Law 240/2010, as amended, and to the relevant provisions of the recruiting universities.

By submitting an application to participate in the selection procedures the candidate accepts the rules contained in this call and in the Regulations governing PhD programmes, the Regulations governing research fellowships and the regulations pertaining to the FutureData4EU project.

The FutureData4EU boards have the right to verify the accuracy of the declarations in lieu of certifications or affidavits submitted by the candidates and pursuant to Presidential Decree 445/2000 at every stage of the procedure. Should the above-mentioned check reveal that the declarations are inaccurate, the declarant will lose any benefits arising from any decision issued on the basis of an inaccurate declaration, without prejudice to the provisions of Article 76 of Presidential Decree 445/2000 on sanctions pursuant to the Italian Criminal Code and related special laws.

The responsible person for the procedure is Dr. Verdiana Bandini, Head of the Research Division (ARIC) at Alma Mater Studiorum - University of Bologna.



ALMA MATER STUDIORUM | RESEARCH  
UNIVERSITÀ DI BOLOGNA | DIVISION



For clarifications or further information about this call, please contact [cofund@unibo.it](mailto:cofund@unibo.it).

This call has been translated into English solely for informational purposes; only the Italian version will be valid for all legal purposes.





ALMA MATER STUDIORUM | RESEARCH  
UNIVERSITÀ DI BOLOGNA | DIVISION



**FutureData4EU**

Training Future Big Data Experts for Europe

## Annex 1 – FutureData4EU doctoral positions and research themes

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### Doctoral Position

#### **BISTAT - Big data and statistical theory for enhanced inferences in domain sciences**

### Doctoral Programme

Statistical Sciences

### Description of the doctoral position's main topic

The increasing need to formalize and analyse complex problems in various sectors of society has underlined the importance of converting the abundance of complex data available in many fields into knowledge, leading to innovation and development. Technological advancements in detecting, organizing, and storing information from communities of individuals, public and private entities, as well as continuously connected detection tools have not only increased the quantity of data and their availability but also transformed their structure. In this process, statistics plays a pivotal role, facing two interconnected challenges: complexity and high dimensionality. The complexity arises from the diverse sources of data, accuracy issues, and the timing of observations, while high dimensionality is characterized by the volume, speed, variety, and combinations thereof, such as the 'large p, small n' scenario. These challenges necessitate ad hoc statistical methods to effectively transform data into knowledge. Complex and high-dimensional data do not fall within the purview of traditional statistics. To address some of the critical issues they pose, various methodological and applied proposals have emerged in recent literature. These, arising in response to specific problems, exhibit specific characteristics of the contexts in which they were developed. On the other hand, the development of the statistical discipline demonstrates that the results obtained in one context generally have much broader applicability. The "portability" of methods and models to different application contexts from those in which they were developed is also linked to the definition of general and unifying approaches.

This project aims to contribute to the definition of general approaches for inference with complex data of different natures, which serve as a methodological infrastructure for the definition of appropriate modeling, forecasting, classification strategies, etc. The focus will be on two main objectives:

(i) addressing the complexity of data by formulating new methods and models for unconventional data structures, such as multivariate data (space-time or multivariate panel data), relational data, mixed type data,

and multilevel data (where observations are nested within known groups) or sets of diversified data from multiple sources;

(ii) circumventing problems arising from high dimensionality by defining new statistical procedures based on projections, regularization, variable selection, or derivation of new estimation procedures.

These approaches will be used to meet the growing demand for solving complex problems in various application sectors. In particular, the main challenges in the field of health will be considered, where widespread or systematic application of statistically principled solutions is still far from being practiced. Collaborating with local healthcare providers and policymakers, the research will address regional needs and contribute to national and healthcare solutions. Globally, the research will align with international endeavours to harness the potential of data in healthcare and add to the expanding knowledge in the field. Potential career opportunities could include academic positions as a research scientist or faculty member, as well as roles in industry such as data scientist, healthcare analyst, or consultant for healthcare organizations.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Monica Chiogna, Maria-Pia Victoria Feser, Christian Martin Hennig

### Doctoral candidate's desirable skills and competences

#### **Scientific and technical skills**

Applicants must have obtained (or be about to obtain), an MSc/MRes/MPhil (or equivalent) in any of the ERC PE1 Mathematics fields or in the following ERC Life Sciences fields: biostatistics, bioinformatics, computational biology.

#### **Soft skills**

Applicants should possess outstanding abilities in both written and verbal English, demonstrate a collaborative mindset, and exhibit strong organizational skills. Additionally, they should be open to participating in interdisciplinary collaborative research on a global scale and be prepared to travel for research, workshops, and conferences.

#### **Other skills**

Favorable qualifications that would give applicants an advantage for this position include familiarity with computing languages such as R, Python, or other relevant languages. Experience with the analysis of big data would also be beneficial. Additionally, experience with scientific publishing and open science practices would be advantageous.

## Description of the research group(s) in which the doctoral candidate will be integrated

The research group at the Department of Statistical Sciences, University of Bologna, that will be involved in this project conducts cutting-edge research in several areas including the design of experiments, statistics in medicine, and statistical genomics. The group focuses on developing innovative methodologies for experimental design, data analysis, and interpretation in various scientific fields. Their research encompasses a wide range of statistical techniques and computational tools to address complex problems in medical research and genomics. The group has expertise in advanced statistical modelling, bioinformatics, and machine learning, and has produced significant results in the development of new statistical methods for personalized medicine, genetic association studies, and analysis of high-throughput genomic data. For more detailed information about the group's research activities and achievements, additional details can be found on their respective web pages:

<https://stat.unibo.it/it/ricerca/ambiti-di-ricerca/design-of-experiments>

<https://stat.unibo.it/it/ricerca/ambiti-di-ricerca/statistics-in-medicine>

<https://stat.unibo.it/it/ricerca/ambiti-di-ricerca/statistical-genomics> <https://stat.unibo.it/it/ricerca/ambiti-di-ricerca/classification-and-cluster-analysis>

At a national level, and being the largest department of statistics in Italy, STAT has the responsibility to ensure the advancement of the discipline in a wide range of research areas, consolidating its leading role. The doctoral program is the tool through which STAT not only aims to confirm its leadership in training data scientists but also to become an important reference for strengthening public-private collaboration, applied research, innovation capacity, and the link between research and societal challenges. The faculty of the doctoral program plays a significant role in international debates on data science and statistics; they hold scientific leadership positions in the most important national and international scientific associations (such as The International Environmental Society – TIES, the International Federation of Classification Societies – IFCS, among others) and in numerous editorial boards. In recent years, STAT has been involved in numerous research projects, with STAT faculty members often serving as coordinators of scientific teams. Currently, STAT manages two projects that have received ERC Consolidator Grants (projects funded by the European Research Council with a total value of ERC = 3.5 million), 12 H2020 projects (total value = 0.35 million), and 1 Erasmus plus KA2 project where STAT has a coordinating role with 14 international partners (value = 1 million). Additionally, STAT has managed 6 projects funded by the Italian Ministry of Research under the National Research Program (PRIN). Finally, STAT coordinates the partnership of an international project funded by the Italian Ministry of Research, ERA-net PEN, with a total value of 0.28 million.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

Doctoral students have access to computer labs equipped with open-source software and all the major scientific and commercial static-econometric software. Library holdings consist of 27,745 volumes covering a wide range of topics in statistics and probability, from historical texts to the latest publications, along with 894 periodicals listed in ACNP. The Department of Statistical Sciences library, <http://www.stat.unibo.it/it/biblioteca>, is an International Statistical Documentation Center and has been ISO 9001 certified since 2004. The library, along with the Bigiavi Library (<https://bigiavi.sba.unibo.it>) and the Department of Mathematics library (<https://matematica.unibo.it/it/biblioteca/bimfi>), part of the university library system, provides access to all volumes of statistical, economic, and probabilistic journals relevant to the doctoral program, including IMS, ISI, and SIAM journals, as well as access to the JSTOR database. Access to databases includes OECD, Econlit, and factual databases such as the World Bank, Eurostat, and limited access to EU-EFIGE and EU-SILC data. Additionally, access is provided to Datastream Bureau van Dijk and other e-resources.

Specific software relevant to the research areas includes SAS, SPSS, R, RStudio, Matlab, Stata, Gretl, E-views, Lisrel, Latent Gold, Python, and Mathematika. Doctoral students in their second and third years have workstations at the department's premises at Viale Filopanti 5. First-year doctoral students have a common room at the proposing department's premises at Via delle Belle Arti 41. Students have access to computers, remote VPN connections, university proxies, electronic resources, and super servers for fast computing and management of large datasets.

## Collaboration networks involving the research team

The collaboration network of the research group focusing is a complex web of connections and partnerships. This network includes collaborations with other research institutions, such as universities abroad, public institutions dedicated to research, supervision, and control within the realm of public health (such as Istituto Superiore di Sanita'), public hospitals at the forefront of health care (such as Istituto ortopedico Rizzoli), institutes for hospitalisation and care of a scientific nature (such as Azienda Ospedaliero-Universitaria di Bologna Policlinico di Sant'Orsola, Istituto Romagnolo per lo Studio dei Tumori ""Dino Amadori"", Istituto di Scienze Neurologiche di Bologna). The group actively engages in interdisciplinary research, working closely with experts in epidemiology, biostatistics, and data science to address pressing health issues. Additionally, the group maintains strong ties also with healthcare firms (such as Alira health, <https://alirahealth.com>) and consulting firms (such as Arithmos, <https://arithmostech.com>) to ensure that their statistical research directly contributes to improving health outcomes. Through these collaborations, the research group can leverage diverse expertise and resources to advance the field of statistical methods for health research and ultimately contribute to the betterment of public health.



The existing network of national and international collaborations offers a wide range of opportunities to organize secondments tailored to the specific needs of the research project to be presented by the recipient candidate of the grant. This network provides access to expertise, resources, and facilities that can greatly enhance the quality and impact of the research, as well as facilitate knowledge exchange and skill development. Leveraging these collaborations can significantly contribute to the success and effectiveness of the research endeavours.

**International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year**

The research group members are actively engaged in several key European and national projects, taking on roles as principal investigators. These collaborative networks provide an invaluable opportunity for the candidate to access a diverse group of experts, offering a wide range of perspectives, methodologies, and resources. Such engagement is expected to significantly enhance the quality and impact of the candidate's work. We list here the main projects at European and national level.

#### ***European Projects***

ESSGN - The European Social Science Genetics Network (MSCA-DN - Grant Agreement n. 101073237).

UNIBO Research Unit Coordinator: Nicola Barban.

Project duration: 48 months (01/03/2023-28/02/2027).

POPCLIMA - Population Dynamics under Global Climate Change (ERC Consolidator Grant - Grant Agreement n. 101002973).

Principal Investigator: Raya Muttarak.

Duration: 60 months (01/01/2022-31/12/2026).

GENPOP – Genes, genealogies and the evolution of demographic change and social inequality (ERC Consolidator Grant - Grant Agreement n. 865356).

Principal Investigator: Nicola Barban.

Project duration: 60 months (01/10/2020 – 30/09/2025).

#### ***National projects***

SOFIA – SOcial and health Frailty as determinants of Inequality in Aging (PRIN Bando 2020).

UNIBO Research Unit Coordinator: Rossella Miglio.

Project duration: 36 months (19/05/2022 – 19/05/2025).

Ita-GENPOP – Family networks and long-term population change in Italy (FARE 2020 MUR).

Principal Investigator: Nicola Barban.

Project duration: 48 months (01/12/2022 – 30/11/2026).

## Doctoral Position

### **Enhancing Dermatologic Interventions through Big Data-Driven Understanding of Placebo Effects**

## Doctoral Programme

Surgical Sciences and Innovative Technologies

### Description of the doctoral position's main topic

The doctoral research within the COFUND research project 'Futuredata4EU' will focus on advancing our understanding of placebo and nocebo effects in dermatology, as outlined in the project's overarching aim. This research topic holds significant relevance due to its potential to revolutionise dermatologic treatment strategies and enhance patient outcomes.

At the regional level, the project aims to collaborate with dermatology clinics and research centres to collect diverse datasets encompassing patient demographics, clinical profiles, and treatment outcomes. The project's findings will contribute to addressing critical gaps in psycho-neuro-biological research within dermatology, aligning with national priorities for advancing healthcare innovation and personalized medicine. By leveraging big data analytics and machine learning techniques, the research will pave the way for novel therapeutic approaches tailored to individual patient characteristics and expectations, thus enhancing the effectiveness and sustainability of dermatologic treatments nationwide. The project will engage with national and international leading experts in placebo and nocebo, dermatology, neuroscience, and data science. This international collaboration will facilitate the data collections and the dissemination of research findings, establishment of best practices, and potential harmonization of clinical trial designs across borders, ultimately benefiting patients worldwide. Moreover, participation in this doctoral research offers candidates a unique opportunity to delve into cutting edge interdisciplinary research at the intersection of psychology, dermatology, neurobiology, and data science. The project's emphasis on creativity, independence, and innovation aligns with the career aspirations of aspiring researchers, providing a solid foundation for future career advancement in academia, industry, or clinical practice.

Candidates embarking on this doctoral research journey will have the chance to develop their own project ideas within the broader research topic of placebo and nocebo effects in dermatology. This opportunity fosters creativity and critical thinking, empowering candidates to shape their research trajectory and contribute novel insights to the field. Furthermore, the interdisciplinary nature of the research opens doors

to diverse career pathways, including academia, healthcare management, pharmaceutical research, and data science, thereby enhancing the candidates' employability and professional growth prospects.

In summary, the doctoral research within the COFUND project 'Futuredata4EU' offers a dynamic and intellectually stimulating environment for candidates to explore the intricate relationship between patient expectations, treatment outcomes, and neurobiological mechanisms in dermatology. With its regional, national, and international implications, this research topic promises to catalyse innovation in dermatologic care and provide candidates with valuable skills and opportunities for future career development.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Katia Mattarozzi, Bianca Maria Piraccini, Gastone Castellani, Emanuela Marcelli, Arianna Bagnis, Andrea Evers.

### Doctoral candidate's desirable skills and competences

#### ***Scientific and technical skills***

Expertise in placebo and nocebo effects, with a strong understanding of neurobiological mechanisms underlying these phenomena.

Proficiency in dermatology, including knowledge of dermatologic conditions, treatment modalities, and patient care.

Demonstrated research experience in related fields, preferably with a focus on psychosocial aspects of healthcare and clinical trials.

#### ***Other skills***

Familiarity with big data analytics and data mining techniques, enabling the candidate to analyse diverse datasets effectively.

Experience in interdisciplinary research, particularly in collaborative projects involving multiple scientific disciplines.

Proficiency in statistical analysis software such as R or Python, facilitating data interpretation and modelling.

### Description of the research group(s) in which the doctoral candidate will be integrated

Katia Mattarozzi, Associate Professor of Psychology at the University of Bologna, leads research focused on top-down modulation of pain and Patient-Reported Outcome Measures (PROMs). She also spearheads the

PANACEA ERASMUS+ Programme, which explores "Special Needs by Placebo" to Advise, Normalize, and Control its European Administration.

Bianca Maria Piraccini, Full Professor in Dermatology at the University of Bologna, specializes in disorders of skin appendages, hair, and nails, providing invaluable clinical insights into dermatologic conditions. Gastone Castellani, Full Professor of Applied Physics at the University of Bologna, brings expertise in big data and algorithmic decision-making, leading EU projects such as HARMONY, Genomed4All, and SYNTHEMA, all dedicated to Big Data Analytics and Machine Learning.

Emanuela Marcelli, Associate Professor of Biomedical Engineering at the University of Bologna, offers expertise in utilizing innovative technologies and sensors to monitor health conditions and assess therapeutic treatment effects in patients.

Arianna Bagnis, Postdoctoral Researcher at the University of Bologna, focuses on top-down modulation of pain and serves as project manager of the PANACEA program, further enhancing the group's understanding of placebo mechanisms.

Furthermore, the collaboration with Andrea Evers, Full Professor of Health Psychology at the University of Leiden, strengthens the group's expertise in placebo studies, particularly in dermatology, through their long-term partnership in the PANACEA ERASMUS+ project. The group's affiliation with the European Academy of Dermatology & Venereology (EADV) provides access to a broader network of dermatologists and researchers, fostering knowledge exchange and collaboration.

### Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

Candidate will have access to robust computing resources necessary for processing and analysing large-scale datasets such as in-house cluster of 20 servers, equipped with 64-core Xeon processors, >20TB Hard Disk and 256 GB RAM each, for bioinformatics analyses purposes, equipped with all available software suites (Python, R, Julia, Matlab, C++). Leveraging big data methodologies, including data mining and machine learning algorithms, our computational infrastructure will enable the integration and analysis of diverse datasets such as Randomized Controlled Trials (RCTs) data, electronic health records, and patient-reported outcomes. This computational framework will serve as the cornerstone for identifying patterns and predictors associated with placebo and nocebo responses, ultimately leading to the development of predictive models for treatment outcomes.

### Collaboration networks involving the research team

- European Academy of Dermatology & Venereology (EADV)

- A non-academic institution providing access to a broader network of dermatologists and researchers. EADV serves as a platform for knowledge ex-change and collaboration, further enriching the program's scientific ecosystem.
- Panacea Cooperation Partnership <https://site.unibo.it/educationonplacebo/en>
- SIPS <https://placebosociety.org/home>
- EFIC <https://europeanpainfederation.eu/>
- University of Cambridge UK
- Politecnica University of Madrid ESP

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

Project HARMONY; Funding: Innovative Medicines Initiative (IMI) and European Union's Horizon 2020 Research and Innovation Programme and the European Federation of Pharmaceutical Industries and Associations (EFPIA); Unit Project Leader: Gastone Castellani, University of Bologna;

Project: Genomed4All; Funding: European Union's Horizon 2020 research and innovation programme under grant agreement No 101017549; Unit Project Leader: Gastone Castellani, University of Bologna;

Project: SYNTHEMA; Funding: European Union Horizon Europe; PI: Gastone Castellani, University of Bologna; all devoted to Big Data Analytics and Machine Learning, University of Bologna.

Project: PANACEA "Special Needs by Placebo: Programme to Advise, Normalize and Control its European Administration (PANACEA)"; Funding: European Commission, Action Erasmus+ Ka220-HED Cooperation Partnerships; PI: Katia Mattarozzi, University of Bologna.

## Doctoral Position

### Data driven determination of statistical properties of proteins

## Doctoral Programme

Physics

### Description of the doctoral position's main topic

Proteins are the molecules that translate into action the information stored in DNA. Their properties (function, pathogenicity, therapeutic properties) depend on their shape and dynamics. In the last few years immense progresses have been made in predicting such properties using physical principles, steadily growing databases of sequences and structures, and the integration possible through statistical and machine learning. The aim of the project is to refine and extend the scope of predictions integrating any information obtained from experimental probes.

In particular, hydrogen-deuterium exchange mass spectrometry (HDX-MS) is emerging as a high-throughput probe of properties that are unique to proteins' structure and function. It provides ambiguous but low noise information (<https://doi.org/10.1016/j.bpj.2019.02.024>, <https://doi.org/10.1021/jasms.2c00005>) that is highly promising in designing, modifying and testing the design of therapeutic proteins. Also, it is ideally suited to the study of high entropy states of proteins (e.g., intrinsically disordered) involved in many diseases which are difficult to characterise and hence to interfere with.

The research will be supported by an international and interdisciplinary network of collaborators,

Which includes experimentalists (Frank Sobott and Vincenzo De Filippis, specialists in mass spectrometry at University of Leeds, UK, and University of Padua, IT, respectively, Roman Tuma, biophysicist at University of South Bohemia, CZ), biostatisticians (Jeanine Houwing-Duistermaat at Radboud University, Nijmegen, NL) and a biotech startup (Peptone Therapeutics, in Bellinzona, CH).

### Sub-themes of the doctoral position's main topic (if any)

The proposal closely fits with the "enabling technology" theme in that it aims to provide an integrative tool that uses data from biophysical experiments and provides testable properties novel biological therapeutics.

## Potential Supervisors

Emanuele Paci, Claudia Testa, Alessandra Merlotti, Roman Tuma, Jeanine Houwing-Duistermaat, Vincenzo De Filippis, Frank Sobott

## Doctoral candidate's desirable skills and competences

### ***Scientific and technical skills***

The candidate should hold a Master's degree in Physics, Chemistry, Biochemistry, Mathematics, Statistics or an equivalent degree, or will have completed such a degree before the start date.

The candidate should have some research experience in one of these fields: computational or experimental biophysics, computational chemistry, statistical analysis of biophysical data, bioinformatics, machine learning, large language models.

### Description of the research group(s) in which the doctoral candidate will be integrated

The research group recently relocated at UNIBO and includes a post-doctoral researcher and a doctoral student. The team leader is part of the "Applied" sector, composed by a number of researchers with their own research lines in the very broad field of applied physics. The team leader web page is <https://www.unibo.it/sitoweb/e.paci/>, and for a reference to the research conducted in my group check <https://scholar.google.co.uk/citations?user=J1Ehb3AAAAAJ&hl=en>

### Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The doctoral candidate will have access to the equipment needed for daily work. Access to departmental computing resources.

### Collaboration networks involving the research team

The success of the project relies on a broad network of national and international collaborators. Particularly relevant to the project is the collaboration with experimentalists (for example, Frank Sobott and Vincenzo De Filippis, specialists in mass spectrometry at University of Leeds, UK, and University of Padua, IT, respectively, Roman Tuma, biophysicist at University of South Bohemia, CZ) biostatisticians (Jeanine Houwing-Duistermaat, Radboud University, Nijmegen, NL) and a biotech startup (Peptone Therapeutics, Bellinzona, CH).

### International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- Protein function from disorder. Insight from single molecule optical tweezers, physical models, and computation, E. Paci (PI) C. Cecconi (co-I) PRIN2022;
- Revealing complexity of hyaluronan-protein interactions: novel tools and insights Ralf Richter (PI), E. Paci et al. (co-applicant) (04/23-03/26);



- Does functional misfolding of TonB drive import across the outer membrane of Gram negative bacteria? (04/22-03/25) D. Brockwell (PI), E. Paci, T. Karamanos (Co-I);
- Design of novel vectors for gene therapy, Innovate UK-Freeline Therapeutics Ltd E. Paci (PI) (01/20-12/23);
- Rational design of dynamic molecules for; enhanced multivalent binding, Leverhulme Trust, Paci E (PI), Turnbull B (co-I) (01/19-12/22).
- Exploiting the SARS-CoV-2 nsp14 3'-5'-exoribonuclease as a target for antiviral chemotherapy, MRC-UKRI Covid-19 call (05/20-08/21). M. Harris (PI), E Paci (co-I).

## Doctoral Position

### **AI-based neurobiological phenotyping of patients with expansion repeats and brain disorders**

## Doctoral Programme

Biomedical and Neuromotor Sciences

## Description of the doctoral position's main topic

The main aims of all ongoing and future activities of our research group are the comprehension of pathophysiological bases of neurodegenerative diseases and identification of diagnostic and predictive biomarkers. The wide range of potential studies that the PhD candidate could develop will be very important for achieving personalized cognitive and/or motor rehabilitation treatments.

Expansion repeats disorders such as familial form of Amyotrophic Lateral Sclerosis (ALS), Myotonic Dystrophy type 1 (DM1) and type 2 (DM2), Huntington's disease (HD), and Spinocerebellar Ataxias (SCAs), affect mainly the central nervous system and/or the neuromuscular system and several of them may imply multisystemic involvement. These disorders are characterized by unstable short tandem repeats, which are 3-12 bp long repeating tracts of DNA in coding and non-coding regions. Several studies have investigated the correlation between the size of the repeat expansion and the clinical phenotype (age at onset, motor and cognitive severity), but there is an urgent need to better understand the somatic instability phenomenon, which modulates the size of repeats across different tissues and cells throughout an individual's lifetime. The candidate will develop an innovative diagnostic approach in blood or in unconventional specimens using third generation DNA sequencing techniques (GridION, Oxford Nanopore, UK), going beyond standard methods based on Southern blotting. This approach will allow the concomitant analysis of genetic and epigenetic patterns in the assessed samples. Additionally, the candidate will be involved in assessing non-invasive brain functional MRI techniques, neuropsychological evaluation and neurorehabilitation in order to design artificial intelligence (AI) approaches capable of extracting and integrating multimodal relevant features for improving the current classification of patients.

Valuable connections between the research group and researchers working both locally and internationally will enhance the specific expertise that the project can call upon. These include multimodal data analysis: Pietro Liò, Full Professor, Cambridge University; bioinformatics: Mauro Castelli, Associate Professor, Universidade NOVA de Lisboa; computational methods for brain connectome: James V Haxby, Full Professor, University of Dartmouth, USA; sleep disorders in neurodegenerative diseases: Giuseppe Plazzi, Full Professor, UNIMORE; neuropsychology and cognitive rehabilitation: Micaela Mitolo, RTD, UNIPR.

As a highly trained professional researcher, capable of independently designing and conducting studies in the sectors of biocomputational, biomedical and biotechnological sciences, the PhD student will gain national and international career opportunities both in the higher education sector and industrial fields allied to the health sciences (biotechnology, medical devices, pharmaceutical), along with a wider range of prospects for data science careers in both the public and private sectors.

### Sub-themes of the doctoral position's main topic (if any)

Neurodegeneration, Expansion repeats disorders, Multi-omics, Cognition, Functional Connectivity, Resting state fMRI.

### Potential Supervisors

Caterina Tonon, Luca Morandi, Alessandra Merlotti.

### Doctoral candidate's desirable skills and competences

#### ***Scientific and technical skills***

The ideal candidate should possess a good grasp of statistics techniques and be eager to do research at the interface of AI and neuroscience. Familiarity with machine learning and AI methods applied to medicine is desirable.

Basic scientific knowledge should include normal human brain morphology, ultrastructure and physiology, and the molecular bases and phenotypic characteristics of pathological processes. Knowledge of the following topics will be positively evaluated but is not mandatory before the project starts: aspects of molecular biology experience of PCR and NGS methods, statistical analysis methods for data interpretation and proficiency in programming languages such as bash, Python, and MATLAB for efficient data processing. All these skills will be further developed throughout the project.

#### ***Soft skills***

Adaptability and a willingness to learn new skills are equally important, as well as the ability to integrate diverse approaches to tackle complex research questions effectively. Moreover, it is important for the candidate to demonstrate the ability to collaborate with researchers from diverse backgrounds, fostering interdisciplinary teamwork.

### Description of the research group(s) in which the doctoral candidate will be integrated

The Lab Team has competence in a) genetics and epigenetics of neurological disorders, including brain expansion repeat disorders, narcolepsy, and brain cancer. Experimental activities include expansion repeat analysis by Oxford Nanopore technology in DM1 from whole blood and olfactory brushing, HLA genotyping by Oxford Nanopore Technologies and DNA methylation analysis in narcoleptic patients from cerebrospinal

fluid, olfactory brushing and whole blood; glioma classification using Illumina NGS protocols; b) metabolomics. Our clinical and neuropsychological teams work in synergy with the neuroimaging research group that is dedicated to advancing functional, metabolic, and structural imaging of central nervous system disorders. The group's research covers a broad spectrum of topics in quantitative neuroimaging, encompassing both the development of innovative MRI sequences and their applications in the clinical setting. Primary research areas include application of functional MRI techniques, including highly temporally resolved resting-state fMRI functional connectivity for evaluating motor rehabilitation using exoskeleton, and the optimization of <sup>23</sup>Na MRI and Quantitative Susceptibility Mapping (QSM) for characterization and early detection of neurodegeneration. The neuroradiological and technical-MRI development teams within this group are involved in the design and implementation of experimental protocols to explore possible associations of the cognitive characteristics with the neuroanatomical and neurofunctional aspects and genetics in neurological disorders. Additionally, current research studies involve the design of fMRI during naturalistic stimuli (film watching). The neuropsychological team presents transversal skills: from a clinical perspective, it provides psychological assessment and intervention protocols, including telerehabilitation. The AI group is devoted to the development of machine learning, deep learning, and artificial intelligence techniques suitable for biophysical data or biomedical databases, modelling and analysis of biological and biomedical data (multiple omics, next-generation sequencing, bioimaging, text mining) with bioinformatics and artificial intelligence methods.

### Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The facility at the Neurogenetic lab (Bellaria Hospital) is equipped with GridION DNA sequencer (Oxford Nanopore), NovaSEQ6000 DNA Sequencer (Illumina) NextSEQ500 DNA Sequencer (Illumina), MiSEQ DNA Sequencer (Illumina), MicroLC-TripleTOF 6600+ (Sciex, Concord, ON, Canada) for MS data acquisition, PeakView, ProteinPilot and MarkerView (Sciex, Concord, Ontario, Canada) for data processing Laser Assisted Tissue Microdissector (Leica).

Neuroimaging Lab is equipped with high field MR 3-T scanner (Siemens), high-resolution head proton coil, high-resolution head <sup>23</sup>Na coil MRI, scanning time for research purpose (optimization of MR acquisition techniques, test on phantoms, patients and healthy control population scanning).

The computational resources needed for data analysis are provided by two high performance PCs equipped with RTX A5000 GPUs, a Linux server hosted at the LEPIDA data centre, and both data storage and HPC facilities for genomic data analysis available to the consortium created by the IRCCS ISNB and CINECA.

## Collaboration networks involving the research team

- ERN-RND (European Reference Network for neurological diseases, for neuromuscular diseases, and for rare or low prevalence neurological diseases): <https://www.ern-rnd.eu/ern-rnd-registry/>;
- Enroll-HD, <https://www.enroll-hd.org/>;
- ENIGMA (Enhancing NeuroImaging Genetics through Meta Analysis Consortium) ;
- RIN Neuroimaging Network (IRCCS Network of Neuroscience and Neurorehabilitation) <https://www.reteneuroscienze.it/en/profilo/>

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

Health Big Data: Virtual Institutes of Pathology of the Italian Network of IRCCS, preventing diseases, personalizing treatments, improving the quality of life of patients IRCCS ISNB through RIN network Ministry of Health, Italy 2019-2028. Raffaele Lodi, participant for advanced analysis tools of clinical, laboratory and imaging data of neurological disorders.

EraPerMed 2021 Artificial intelligence for personalised medicine in depression - analysis and harmonization of clinical research data for robust multimodal patient profiling for the prediction of therapy outcome (ArtiPro)". 24-05-2021 al 23-05-2024 Maria Giulia Bacalini, participant.

From Stratification to Personalized Imaging in Neurology/Neuroscience: growing the synergy between high and ultrahigh field MRI in the RIN network (SPIN) IRCCS ISNB Ministry of Health, Italy RCR2022-2024. Caterina Tonon, participant.

MNESYS - A Multiscale integrated approach to the study of the Nervous System in Health and Disease IRCCS ISNB Ministry of University and Research – MUR, Italy 2022-2025. Maria Giulia Bacalini, participant for the identification of early neurodegeneration biomarker; Gianfranco Vornetti and Caterina Tonon, participant for multiparametric imaging biomarkers of neurological disorders

DARE Digital Lifelong Prevention IRCCS ISNB Ministry of University and Research – MUR, Italy 2022-2026 Rare Neurodegenerative diseases: Longitudinal Multi-domains. PNRR (2022-2026)

“Radiogenomics for Early detection of Alzheimer's Disease: combining DNA methylation-based liquid biopsy and advanced Magnetic Resonance Imaging”, Funding: AirAlzh. PI: Maria Giulia Bacalini Radiogenomic approach for the study of neurodegeneration in Alzheimer’s disease spectrum (cognitive subjective decline, mild cognitive impairment, Alzheimer’s disease).

Neuropsychological and Multi-nuclear advanced MR Imaging phenotyping of patients with HSP and ASL IRCCS ISNB RC2023-2024. PI: Magali Jane Rochat, participants: all the researchers of the neuroimaging and lab unit.

## Doctoral Position

### **Evolutionary perspective on health and medicine through the lens of paleogenomics**

## Doctoral Programme

Life Sciences and Biotechnology

### Description of the doctoral position's main topic

Disentangling the history of human biological adaptation has fascinated scientists for more than a century. How did humans evolve in response to the new environments they encountered while expanding from Africa? How ancient human populations responded genetically to cultural changes such as the dietary shifts associated with the onset of agriculture? Do our past adaptations have consequences for health and medicine today?

Since 2010, advancements and the subsequent broad applications of next-generation sequencing techniques have enabled rapid and cost-effective sequencing of eukaryotic genomes and paved the way for a genomic era in the field of ancient DNA, which is now established as a new discipline, called Paleogenomics. Ancient DNA provides a glimpse into the genetic history of humans across the globe over the past millennia. The study of paleogenomic data made it possible to examine the deep past of human populations, and to explore the genetic makeup and adaptation dynamics of archaic lineages and of ancient and present-day populations. The sequencing of Neanderthal and Denisovan genomes has revealed a complex history of admixture between archaic humans and the ancestors of modern humans. Consequently, archaic sequences became part of the modern human gene pool, possibly influencing life and health of our ancestors, as well as of living individuals. For example, lines of evidence suggest that genetic variants introgressed from archaic hominins may have affected genes associated with immunity, or pharmacogenes - genes involved in drug metabolism - as these genes can relate to changing environments, and beneficial variants may have been positively selected by modern humans. In addition, modern human population dynamics had a pivotal role in shaping the current pattern of genomic diversity. Within the past 10,000 years, we observed two main genetic turnovers in Europe, namely the Neolithic transition and the expansion of farming communities from Anatolia, and the migration from Pontic-Caspian Steppe during Bronze Age. These population dispersals, changing lifestyle and higher population density, may have resulted in increased transmission of pathogens, driving selection of variants in immune response genes, and triggered important changes in the adaptive evolution of our species both at local and global scales. While the availability of thousands of ancient genomes gives us the opportunity to unveil the history of human adaptation at unprecedented depth and precision, the study of the contribution of archaic and ancient alleles to current human health is still in its

infancy. Shedding light on adaptive evolutionary dynamics of our species would promote a more comprehensive reconstruction of our past, sharpening the current understanding of our present. The results of this project will pioneer the field of Evolutionary Medicine, thus providing significant contributions to biomedical research and medical applications.

### Sub-themes of the doctoral position's main topic (if any)

The availability of thousands of high-quality ancient genomes can help the identification of rare variants introgressed from archaic and ancient humans into the modern populations to address key questions related to human health and disease. Studies on modern humans shown that differential outcomes after infection are due to specific DNA mutations that alter host defense mechanisms. However, little is known about adaptation of archaic and ancient humans to past environments and pathogens. Therefore, studying genetic variants associated with infectious-disease risks in fossil remains, highlight the potential value of paleogenomics in medicine.

Recent studies pointed out the value of using ancient DNA to reconstruct the evolutionary history of immune disorders and past epidemics. Kerner et al. (2021) found a tuberculosis risk variant in ancient genomes that has evolved under strong negative selection over the past two millennia, probably reflective of the pressure imposed by *Mycobacterium tuberculosis*. Ancient DNA can also be used to identify advantageous mutations that are positively selected over time through pathogen exposure. For example, some immunity-related genes under positive selection have been found to be associated with the Neolithic transition in Europe. This is the case for *IL1R2*, for which high levels of expression are associated with protection against several autoimmune disorders.

Lastly, the study of genetic variants inherited from the admixture between modern and archaic humans can help us to disentangle adaptation processes to new environments and host resistance to pathogens. An example is the adaptation of Tibetan populations to high altitudes due to the introgression of adaptive alleles from Denisovans. Another case is provided by a Neanderthal haplotype at the antiviral *OAS1* that was recently shown to be associated with protection against severe COVID-19. These findings can open new avenues to find candidate drug targets in disease treatment.

Keywords:

- Legacy of archaic humans
- Immune disorders
- Adaptation to pathogens
- Co-evolution pathogens-host

### Potential Supervisors

Silvi Ghirotto, Andrea Benazzo, Silvia Fuselli

## Doctoral candidate's desirable skills and competences

### ***Scientific and technical skills***

The ideal candidate should have a graduate degree in biology, genetics, or a closely related field, and a strong interest in bioinformatics. The candidate should have a good computational background (basic knowledge of R, Python or Bash programming languages are mandatory); experience with cluster computing environments would be appreciated but it is not mandatory. He/she should also have a good population genetics background.

The work will focus intensively on bioinformatics and biostatistics to handle and analyze genomic data. The candidate will have a primary role in the processing and management of genomic data (ancient and modern), as well as the development of methods to infer demographic and evolutionary processes using genomic data.

### ***Other skills***

We are looking for a motivated PhD candidate, hardworking, and interested in addressing scientific problems with rigor and creativity. The candidate will need to communicate and write in English; fluent level of English is recommended.

## Description of the research group(s) in which the doctoral candidate will be integrated

The candidate will be supervised by Prof. Silvia Ghirotto (associate professor at UNIFE since 2018, total citations 1395, h-index 23, (Scopus, 19/03/2024), qualified to full professor in Genetics and in Anthropology in 2021), a geneticist specialized in population genetics. She published 50 original papers, almost all about population genetics analysis of human evolutionary history and development of methods for the analysis of genomic data. The complete list of Prof. Ghirotto's publications can be found here: <https://scholar.google.com/citations?hl=it&user=ZiSeXplAAAAJ>. At the moment, Prof. Ghirotto is leading a national project involving five different academic units, aiming to reconstruct the demographic and evolutionary history of human presence in the three main Mediterranean islands (Sicily, Sardinia and Corsica); she is also responsible for the UNIFE unit in other two national projects, aiming to shed light on the past human dynamics in the Italian peninsula and to perform evolutionary inference of past processes from dental calculus metagenomic data. She is also directing a national project aiming to study the origin of social inequalities in Northern Italy from a paleogenomic perspective. Prof. Ghirotto coordinates a research group composed by two postdoctoral researchers, two PhD students, and a fellowship researcher. The research group has extensive experience in bioinformatic analysis and in statistical methods applied to the analysis of modern and ancient genomic data. The research work focuses on the reconstruction of evolutionary processes that shaped current and past patterns of genomic variation, exploring and interpreting human genetic variation together with evidence from other fields, such as anthropology, archaeology, and linguistics. Prof. Ghirotto group is also primarily involved in the development and the analysis of statistical



methods, mainly based on computer simulations and machine learning approaches, to infer past population dynamics and to test among different evolutionary scenarios. Prof. Ghirotto research group is integrated within the Population Genomics laboratory of the University of Ferrara. The Population Genomics laboratory team is composed by Prof Guido Barbujani, whose research focuses on human evolutionary genetics, Prof Giorgio Bertorelle and Dr Andrea Benazzo, whose research focuses on evolutionary and conservation genomics, Dr Silvia Fuselli, whose research focuses on molecular evolution and pharmacogenomics, Prof Chiara Scapoli and Dr Elisabetta Mamolini, whose research focuses on human genetics.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The host will give all the support in the completion of the project goals. Life Sciences and Biotechnology Department at UNIFE has a long-lasting tradition of advanced studies in populations genetics and genomics, micro and macro evolutionary processes and biostatistics. It has a large team of people working in transversal and multidisciplinary themes. It frequently hosts visiting researchers. The doctoral candidate will be integrated into Prof. Silvia Ghirotto group, in the Population Genomics laboratory, which has an impressive reputation internationally for the quality and productivity of its members and for the breadth of its expertise. It is a highly attractive laboratory with researchers that cover a broad area of expertise's for the study of populations evolutionary history and development of methods for the analysis of genomic data. Upon beginning of the project, UNIFE will provide a desk space, access to a workstation, web, digital library, high-throughput computational resources, personalized assistance on administrative matters, etc. The host offers magnificent facilities and infrastructure to carry out this project at a European scale. It offers a High-Performance Computing (HPC) System composed by 14 computing nodes, 5 storage servers and 2 login nodes. The total amount of computing resources is 824 cores, 2.9 TB of RAM and 205 TB of storage capacity; access through proposal submission to large CINECA (Consortium of 70 Italian Universities) computing resources. The candidate will have the opportunity to participate in the weekly group seminars, guest talks and discussions sessions to capitalize on local networking chances, increase collaborations with geneticists and bio-statisticians. He/she will be working in an inter-disciplinary environment and in a highly dynamic and enriching research institution. UNIFE have an International Research office providing all the assistance needed to staff and research fellows.

## Collaboration networks involving the research team

The PI of the research group, Prof. Silvia Ghirotto, has been primarily involved in national and international collaborations which aimed to reconstruct past population dynamics through a multidisciplinary approach, and has documented experience in leading research projects, as PI or local coordinator (PRIN 2017, FIR 2018, PRIN 2020, PRIN-PNRR 2022, PRIN 2022). The research group has several well-established national and international collaborations in different fields (anthropology, archaeology, molecular anthropology,

bioinformatics and population genetics) from which the candidate will benefit to ensure the achievement of the project goals. The PI has an established collaboration (since 2015) with the multidisciplinary DFG Center for Advanced Studies "Words Bones Genes Tools" of the University of Tubingen, of which she is an External Scientific Member. Collaborations with national molecular anthropologists from the University of Florence (Prof. David Caramelli, Dr. Stefania Vai and Prof. Martina Lari); international archaeologists from the CNRS in the University of Bordeaux (Prof. Solange Rigaud); populations geneticists from the University of Cambridge (Prof. Andrea Manica) and Muséum National d'Histoire Naturelle in Paris (Prof. Stefano Mona).

### International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- PRIN2017 - 1000 Ancient Italian Genomes: Evidence from ancient biomolecules for unravelling past human population Dynamics (AGED) Ministero dell'Istruzione dell'Università e della Ricerca (MIUR) – Bando PRIN. PI: Prof. David Caramelli. Co-PI: Prof Silvia Ghirotto, Prof. Donata Luiselli, Prof. Olga Rickards, Prof. Sarti Lucia, Prof. Sineo Luca. Team members are responsible for collecting, processing, and analyzing whole genome data from both modern and ancient humans.
- PRIN2020 - Crossing the sea: ancient and modern human genomes to study the evolutionary dynamics of Sicily, Sardinia and Corsica. Ministero dell'Istruzione dell'Università e della Ricerca (MIUR) – Bando PRIN. PI: Prof. Silvia Ghirotto. Co-PI: Dr. Stefania Vai, Prof. Paolo Francalacci, Prof. Luca Sineo and Prof. Marco Sazzini. Team members are responsible for collecting, processing, and analyzing whole genome data from both modern and ancient humans.
- PRIN2022 – Investigating the transition from hunter-gathering to farming in Southern Italy through metagenomic and population genetic analysis of ancient human dental calculus. Ministero dell'Istruzione dell'Università e della Ricerca (MIUR) – Bando PRIN. PI: Prof. Martina Lari. Co-PI: Prof. Silvia Ghirotto. Team members are responsible for collecting, processing, and analyzing whole genome data from dental calculus ancient samples.
- PRIN-PNRR2022 – The origin of social inequalities in Northern Italy: clues from ancient genomes. Ministero dell'Istruzione dell'Università e della Ricerca (MIUR) – Bando PRIN-PNRR. PI: Prof. Silvia Ghirotto. Co-PI: Dr. Stefania Vai. Team members are responsible for collecting, processing, and analysing whole genome data from archaeological human remains.

## Doctoral Position

### **Artificial Intelligence-Based Perioperative Guidance Tool for Vitreoretinal Surgery**

## Doctoral Programme

Advanced Therapies and Experimental Pharmacology

## Description of the doctoral position's main topic

The doctoral research will focus on developing an innovative Big Data-driven Artificial Intelligence (AI)-based perioperative guidance tool tailored for vitreoretinal surgery. Vitreoretinal surgery, a specialized field within ophthalmology, addresses complex conditions affecting the vitreous humor and retina, such as retinal detachment, macular holes, and diabetic retinopathy. While advancements in surgical techniques and instrumentation have improved outcomes, there remains a need for real-time, personalized guidance during surgery to enhance surgical precision and optimize patient outcomes.

**Project Description:** The project aims at leveraging AI and machine learning algorithms based on Big Data to develop a perioperative guidance tool that provides real-time assistance to surgeons during vitreoretinal procedures. The tool will analyse intraoperative data, including surgical images, OCT scans, and patient-specific parameters, to offer decision support and procedural guidance. By integrating AI technology, the tool will assist surgeons in identifying critical structures, planning optimal surgical approaches, and predicting surgical outcomes, thereby enhancing surgical efficiency and safety.

**Connections with Regional, National, and International Context:**

- **Regional:** The project aligns with the regional focus on innovation in healthcare technologies within Emilia-Romagna, Italy. By advancing AI-based solutions for vitreoretinal surgery, the research contributes to regional efforts to foster technological innovation in healthcare and improve patient care outcomes.
- **National:** The research addresses national priorities in healthcare innovation and precision medicine. Italy's healthcare system emphasizes the adoption of cutting-edge technologies to enhance surgical precision and patient safety, making the development of AI-based perioperative guidance tools highly relevant at the national level.
- **International:** The project on Artificial Intelligence-Based Perioperative Guidance Tool for Vitreoretinal Surgery will benefit from strategic partnerships with leading organizations in the healthcare and technology sectors, including Carl Zeiss Meditec AG, Preceyes BV, ACMIT GmbH, and

the University of Bern. These partnerships will enhance the research capabilities, technological expertise, and translational potential of the project.

Potential Career Opportunities: Upon completion of the project, the doctoral candidate will be well-positioned for diverse career opportunities in academia, industry, and healthcare. Potential career paths include:

- Academic Research: Pursuing postdoctoral research positions or faculty positions at universities and research institutions, conducting further research in AI-guided surgical technologies and translational medicine.
- Industry R&D: Joining research and development teams at medical device companies or healthcare technology startups, contributing to the development and commercialization of AI-based surgical guidance systems.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Marco Mura, Massimo Busin, Katia Varani, Paola Secchiero.

### Doctoral candidate's desirable skills and competences

#### ***Scientific and technical skills***

Candidates with a strong background in medical imaging, artificial intelligence, software development, and a willingness to learn about vitreoretinal surgery will be well-suited for the project.

Necessary Requirements:

#### 1. Medical Knowledge:

- Understanding of vitreoretinal surgery techniques, instruments, and procedures.
- Knowledge of common vitreoretinal diseases and their surgical management.

#### 2. Optical Coherence Tomography (OCT) Imaging:

- Knowledge of OCT imaging principles and interpretation of OCT scans in vitreoretinal diseases.

#### 3. Clinical Research Skills:

- Experience in designing and conducting clinical studies to evaluate the effectiveness and safety of medical interventions.

Useful Knowledge:

AI Expertise:

- Proficiency in machine learning algorithms and techniques, particularly in computer vision and image processing.
- -Experience in developing AI models for medical image analysis.
- -Ability to preprocess and annotate medical images for training AI models.

## Description of the research group(s) in which the doctoral candidate will be integrated

The doctoral candidate will have the opportunity to integrate into a dynamic and innovative research group within the Department of Translational Medicine at UNIFE, with a specific focus on ophthalmic surgery and advanced therapies.

The research group specializes in bioengineering and translational medicine, aiming to address critical unmet needs in ophthalmic surgery and related fields. Their research efforts are dedicated to the development of novel surgical instrumentation, ocular prostheses, and robotic microsurgical systems, with a particular emphasis on vitreoretinal surgery. Existing characteristics and skills in the team are described in the following.

The team comprises professors, researchers, technical-administrative staff, postgraduates, doctoral students, research fellows, and collaborators with diverse backgrounds and expertise. The groups has extensive experience in the translation of scientific results into practical solutions, particularly in the field of ophthalmic surgery. The group has strong proficiency in bioengineering, biomedical engineering, and medical device development. The groups collaborate with leading private companies such as Carl Zeiss Meditec AG, Preceyes BV, and ACMIT GmbH, fostering innovation in vitreoretinal surgery.

Most Relevant Results: 1) development of new surgical instrumentation tailored for ophthalmic surgery, enhancing precision and efficacy; 2) innovation in robotic microsurgical systems, facilitating minimally invasive and highly precise surgical procedures; 3) collaborative efforts with industry partners to integrate cutting-edge technologies into clinical practice, improving patient outcomes in vitreoretinal surgery.

Integration of “Big Data”. The research group recognizes the importance of big data and artificial intelligence in advancing healthcare solutions, including ophthalmology. They leverage AI algorithms for medical image analysis, surgical planning, and decision support systems.

PhD Program. The PhD in Advanced Therapies and Experimental Pharmacology offers a unique opportunity for the candidate to acquire high-level skills in pre-clinical and clinical research, focusing on innovative treatments utilizing various therapeutic modalities, including chemical synthesis, biological drugs, and advanced therapies such as cell, tissue, and gene therapies. The program emphasizes translational research approaches, bridging basic science discoveries with clinical applications in ophthalmology. Students engage in interdisciplinary studies encompassing cellular-morphological, biomolecular, pharmacological, and epidemiological research, preparing them for careers at the forefront of therapeutic innovation. Overall, the research group at UNIFE provides a stimulating and collaborative environment for the doctoral candidate to

contribute to cutting-edge research in ophthalmic surgery and advanced therapies, with opportunities to integrate big data and artificial intelligence into translational research endeavours.

Other resources: <https://www.ospfe.it/reparti/oculistica>, <https://mtr.unife.it/it>

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The doctoral candidate will have access to state-of-the-art facilities and resources at UNIFE's Department of Translational Medicine to conduct their research effectively. Here's an overview of the existing facilities available:

### 1. Laboratories:

Laboratorio per le Tecnologie delle Terapie Avanzate - Specialized laboratories equipped for bioengineering, biomedical engineering, and medical device development.

### 2. Equipment:

Unità Operativa Complessa (UOC) di Oculistica dell'Azienda Ospedaliero Universitaria (AOU) di Ferrara - High-resolution imaging equipment for capturing detailed images of ocular structures, including optical coherence tomography (OCT) machines and fundus cameras. Surgical instrumentation for vitreoretinal surgery, including microsurgical tools, intraocular instruments, and visualization systems.

### 3. Computing Resources:

- High-performance computing clusters for data analysis, machine learning, and computational simulations.
- Access to advanced software tools for image processing, medical image analysis, and artificial intelligence development.
- Cloud computing infrastructure for storage and processing of large-scale clinical datasets and bioinformatics analyses.

### 4. Clinical Facilities:

- Unità Operativa Complessa (UOC) di Oculistica dell'Azienda Ospedaliero Universitaria (AOU) di Ferrara - Operating rooms equipped with advanced surgical suites for conducting preclinical and translational research in vitreoretinal surgery.

### 5. Library and Research Support:

- BiblioFE- Polo Bibliotecario Ferrarese: Access to UNIFE's extensive library resources, including online databases, journals, and textbooks in the fields of medicine, bioengineering, and pharmacology.
- UNIFE Ufficio Ricerca Nazionale, UNIFE Ufficio Ricerca Internazionale: Research support services, project management support

## Collaboration networks involving the research team

With its strong network of research and company partners, UNIFE is committed to manage and support the all members of its research team to strengthen innovation capacity and competitiveness, thereby nurturing interdisciplinary and cross-sectoral cooperation with various partners including ACMIT GmbH, Università degli Studi di Verona, Preceyes BV, Universität Bern and Carl Zeiss Meditec AG.

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

1. Project Name: AI guidance for robot-assisted eye surgery (GEYEDANCE)

Funding Scheme: HORIZON Europe - HORIZON-CL4-2021-DIGITAL-EMERGING-01-10

Participants: ACMIT GmbH, Università degli Studi di Ferrara (Prof. Marco Mura, Prof. Massimo Busin, Dr. Angeli Christy Yu), Università degli Studi di Verona, Preceyes BV, Universität Bern

2. Project Name: Pilot Study Testing a Hybrid Intra-Corneal Prosthesis with Dehydrated Corneal Tissue Scaffold for the Treatment of Corneal Blindness (INTRA-KER)

Funding Scheme: Progetti di Ricerca di Rilevante Interesse Nazionale – Bando 2022 PNRR

Participants: Università degli Studi di Cagliari (Prof. Giuseppe Giannaccare), Università degli Studi "Magna Graecia" di Catanzaro (Prof. Vincenzo Scorcìa, Dr. Caterina Battaglia), Università degli Studi di Ferrara (Prof. Marco Mura, Prof. Massimo Busin, Dr. Angeli Christy Yu, Dr. Marco Pellegrini, Dr. Cristina Bovone, Dr. Rossella Spina)

3. Project Name: Development and validation of an Integrated risk prediction model for Corneal graft survival following Endothelial keratoplasty: an artificial intelligence based approach (DISCOVER)

Funding Scheme: Progetti di Ricerca di Rilevante Interesse Nazionale – Bando 2022

Participants: Università degli Studi di Ferrara (Prof. Marco Mura, Prof. Massimo Busin, Prof. Giorgio Zauli, Prof. Evelina Lamma, Dr. Angeli Christy Yu, Dr. Marco Pellegrini, Dr. Rossella Spina)

## Doctoral Position

### **Big-data from single-cell multiomics in somatic stem cells for clinical application**

## Doctoral Programme

Molecular and Regenerative Medicine

## Description of the doctoral position's main topic

Since 1980s, cultures of human epithelial cells (keratinocytes) have been extensively used in clinical applications to regenerate a functional cornea and epidermis in patients affected by severe burns. first successful combined cell and gene therapy for patients suffering from a specific form of Epidermolysis Bullosa (EB), namely recessive LAMB3-dependent Junctional EB (JEB), was pioneered by this research group (Mavilio et al., 2006). This approach relied on the use of transgenic epidermal grafts, prepared from clonogenic keratinocytes cultures transduced with a  $\gamma$ -retroviral vector carrying full-length LAMB3 cDNA (Mavilio et al. 2006, De Rosa et al. 2014, Bauer et al, 2017; Hirsch et al., 2017). It has been demonstrated that combined ex vivo cell and gene therapy can be lifesaving (Hirsch et al., 2017). We were able to restore virtually the entire epidermis of a 7-year-old child with a devastating form of JEB, having very poor prognosis, using a live-saving transgenic epidermal cultures (Hirsch et al., 2017). 8 years after grafting the child's transgenic epidermis is stable and robust (Kuckelhaus et al., 2023). Clonal tracing, using proviral integrations as clonal genetic marks, performed on the regenerated transgenic epidermis, has formally proven that the human epidermis is sustained solely by self-renewing long-lived stem cells. These stem cells, identified as holoclone-forming cells, give rise to pools of short-lived transient amplifying (TA) progenitors, which in turn produce meroclonal and paraclones.

JEB represents a small percentage (~5%) of all EBs (Fine, 2016), and several hindrances hamper ex vivo gene therapy for other forms of EB: i) over 50% of EB forms are dominantly inherited, hence cannot be tackled by viral-mediated gene addition. ii) current gene editing approaches would transduce epidermal stem cells with insufficient efficiency. iii) holoclone-forming cells cannot be prospectively isolated, since specific cell membrane markers allowing their isolation have not yet been identified.

Microarray and single cell RNA-seq data have been used to understand the basic mechanisms of stem cell function in culture (Enzo et al. 2021). We confirm that holoclone-forming cells display stem cell features, such as genes regulating DNA repair, chromosome segregation, spindle and microtubule organization and telomerase activity.



In this project, we aim to combine cutting-edge single-cell transcriptomic and epigenetic data with Artificial Intelligence to better characterize squamous epithelial stem cells at a molecular level. All this data will be used for the creation of an integrated atlas of in vitro cultured human epithelial cells from the different anatomical compartment. The multiomic data will be subjected to machine learning algorithms to develop a user-friendly tools for estimating the characterization of each type of cells, providing a comprehensive understanding of the molecular profile of stem cells, transient amplifying progenitors, and fully differentiated cells from each of these epithelia.

Our international network in regenerative medicine and gene therapy provides a fertile ground for PhD students. Many of these bright minds, having honed their skills and knowledge during their PhD with us, subsequently joined other esteemed groups led by renowned experts in the field. This exchange contributes to the advancement of the scientific community and perpetuates a legacy of excellence and innovation.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Michele De Luca, Graziella Pellegrini, Laura De Rosa.

### Doctoral candidate's desirable skills and competences

#### **Scientific and technical skills**

The candidate should have a Master's degree in science, preferably in molecular biosciences (molecular, cellular, and developmental biology, genetics, or genomics). Practical experience in developmental biology, genetics, microscopy, genomics, or bioinformatics is an advantage.

#### **Other skills**

The candidate should be able to communicate well in both written and spoken English.

### Description of the research group(s) in which the doctoral candidate will be integrated

The research group is led by three principal investigators: Prof. Michele De Luca, Prof. Graziella Pellegrini, and Prof. Laura De Rosa. Additionally, there are three senior researchers (Dr. Elena Enzo, Eustachio Attico, and Eleonora Maurizi) who oversee the coordination of postdoctoral fellows and PhD students. Our research focuses on understanding the molecular mechanisms of self-renewal and differentiation of epithelial cells, as well as the application of cell and gene therapy for various diseases affecting the cornea, skin, and respiratory tract. We conduct primary keratinocyte cultures and perform single-cell transcriptomic and epigenomic experiments, including ATAC-seq and gene expression analysis. Additionally, we employ

proteomic and transcriptomic analyses such as Western blotting, immunofluorescence, real-time PCR, and digital PCR. Furthermore, we develop methods to transduce human primary keratinocytes using lentiviral or retroviral vectors, as well as CRISPR-based gene editing techniques. We developed clinical trials for the use of these cells in clinics. Additional information and full list of publication could be found here: <https://www.cmr.unimore.it/en/homepage-2/>

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The doctoral candidate will conduct her/his activities at the Centre For Regenerative Medicine “Stefano Ferrari” in the University of Modena and Reggio Emilia is a 3-floor building of 4.000 sq metres fully equipped for biochemistry, molecular biology, histology, cytology. Core facilities include confocal and time-lapse microscopy, laser microdissection, X-ray cell irradiation, bioinformatics support, flow-cytometry, 5 fully equipped BL2 cell culture rooms, single-cell transcriptomic platforms (Chromium X from 10X Genomics, Droplet digital PCR from Bio-rad, Tapestry from Mission Bio) and library preparation.

## Collaboration networks involving the research team

Our research team prides itself on its extensive collaboration networks, spanning across various academic disciplines and industry sectors. These networks serve as invaluable resources for doctoral candidates, offering unique opportunities for interdisciplinary exchange, access to cutting-edge technologies, and exposure to diverse perspectives.

Within academia, our team has established collaborations with national and international leading institutions and experts in fields closely related to the Futuredata4EU project. We collaborate with:

- Prof. Bicciato and Prof. Forcato at the University of Padua for the bioinformatic analysis.
- Prof. Paiardini and Prof. Rinaldo for protein structure prediction.
- Dott. Tommaso Selmi from Centro Nazionale delle Ricerche in Milano for epitranscriptomics analysis.
- The European partners in the Regenerate-IT consortium to share methods and tools related to the regenerative medicine field.
- Prof. Mariaceleste Aragona in ReNEW at Copenhagen to study the crosstalk between fibroblast and epithelial cells.

Through these connections, doctoral candidates gain access to specialized knowledge, methodological expertise, and collaborative research opportunities, enriching their academic experience and broadening their professional networks.

Furthermore, our team maintains strong ties with industry partners, including biotech companies (es Holostem s.r.l.), government agencies (es, EMA, Aifa), and non-profit patient organizations (es. Le ali di Camilla). These collaborations offer doctoral candidates real-world insights into the practical applications of

their research, as well as opportunities for technology transfer, industry placements, and entrepreneurship initiatives.

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- Regenerate-IT Learning From Animals How To Regenerate: multidisciplinary training programme in regenerative biology - Marie Skłodowska-Curie Actions – Doctoral Networks (MSCA-DN), PI Michele De Luca
- Custom-designed gene editing of induced epidermal stem cells for gene therapy of genetic diseases of squamous epithelia (HOLO-GT)- - Holo-GT- ERC project, ERC-ADG- Advanced Grant - PI Michele De Luca
- Cellule staminali e medicina personalizzata: il caso della Epidermolisi Bollosa (HG7 3.0) - POR-FESR 2021-2027 PI Michele De Luca
- A plot in vitro and in vivo study for molecular characterization of epidermal stem cells and quality and safety assessment of epidermal cultures for combined cell and gene therapy – PRIN 2022 – PI Michele De Luca
- Gene-editing allele specifico mediato da CRISPR-Cpf1 ingegnerizzate per il trattamento delle patologie oculari nella sindrome da Ectrodattilia-displasia ectodermica-labiopalatoschisi (EEC) - Telethon: PI Michele De Luca
- A new strategic model for a sustainable development and maintenance of advanced therapies on the market- FISA-2022-00928 – PI Graziella Pellegrini
- The Empty Nose syndrome, investigations propaedeutic to in vivo studies – PRIN 2022 – PI Graziella Pellegrini
- High-resolution study of translational dynamics in human epithelial stem cells – PRIN 2022 – PI: Dott. Tommaso Selmi, CO-PI: Elena Enzo

Unravel fibroblast-epithelial crosstalk supporting keratinocytes self-renewal to improve skin graft production. Leo Foundation –PI Prof. Mariaceleste Aragona, Third part: Elena Enzo.

## Doctoral Position

### High-performance computing and data analysis in drug design and discovery

## Doctoral Programme

Drug Sciences

### Description of the doctoral position's main topic

The present proposal is aimed at the setup and use of a computational platform, based on the HPC resources available at the University of Parma, for modelling the mechanism by which covalent drugs interact with molecular targets (i.e., enzymes or receptors) to obtain information useful in the context of drug design and ligand optimization. The effect of a covalent drug is the result of two distinct processes, i. the recruitment of the drug within the binding site of the biological target and, ii. the formation of the drug-target covalent adduct, with generation of a chemical bond modifying the function of the target itself, eventually leading to the insurgence of a therapeutic effect.

The binding path followed by a drug from the solvent bulk to the binding site of a target can be investigated by molecular dynamics (MD), which is a straightforward application of molecular mechanics (MM), that allows to determine the trajectories of atoms through the numerical solution of Newton's equation of motion. The investigation of breaking and formation of covalent bonds requires quantum mechanics (QM) that allows an explicit treatment of the electrons making possible the estimation of the activation barrier (Eact) associated to a specific chemical transformation.

The connection between biochemical events occurring at molecular and electronic level is critical for understanding the mechanism of action of covalent drugs. The aim of this research project is the implementation and use of a HPC platform capable of performing free-energy simulations, based on MM, QM and hybrid QM/MM potentials, to provide thermodynamics and kinetic constants, describing for a given drug both recruitment by the target and reaction with the target, that can be translated into the design of better agents featuring balanced potency and selectivity.

The HPC platform will be applied to the search for new drugs acting on targets critical in the context of neuroinflammatory diseases, including NAAA (N-acyl ethanolamine acid amidase), an Ntn-cysteine hydrolase involved in the hydrolysis of palmitoylethanolamide (PEA), (Piomelli et al, J Med Chem, 2020, Scalvini et al ACS Catal, 2020), and MAGL (Monoacylglycerol lipase), a lipase involved in the breaking down of the endocannabinoid 2-arachidonoylglycerol (2-AG), (Castelli et al J Med Chem 2020, Galvani et al, J Chem Inf Model 2022).

Pharmaceutical applications of multiscale simulations have the potential to leverage covalent drug discovery. We have already exploited their utility applying them in the design of new EGFR covalent inhibitors targeting the front pocket Cys797 (Castelli et al, Eur J Med Chem, 2019) or the catalytic Lys745 (Ferlenghi et al Eur J Med Chem 2021; Arafet et al, J Chem Inf Model 2023). The current proposal will thus reinforce the importance of HPC systems as well as of physics-based simulated data in the drug discovery process.

### Sub-themes of the doctoral position's main topic (if any)

Two different strategies can be applied to identify covalent inhibitors for a given target. Both rely on the presence of a nucleophile, either member of a catalytic machinery or simply with a structural role, in the binding pocket of the protein of interest. In the present proposal two alternative approaches will be taken in consideration:

- In the first approach, a scaffold of a reversible inhibitor already featured by good affinity for the target will be identified and a range of diverse electrophile warheads will be inserted on its structure. Multiscale QM/MM simulations will be performed in an early stage of the project to rank the synthesis of the most promising compounds according to computed data.

- The second approach is based on the virtual screening of libraries of electrophilic compounds of relatively small size. Once a covalent modifier will be identified and verified experimentally, an optimization phase takes place. During this task, the non-reactive portion of the inhibitor will be progressively modified to improve the stereo-electronic complementarity between the target and the inhibitor with the final aim of improving the potency. In this case, the HPC platform will be applied to improve the non-covalent binding affinity of the identified ligands.

Whether a covalent inhibitor will be identified through rational design or in a virtual screening setting, other runs of optimization will be required to properly balance potency and selectivity. Again, this task will be done by modifying the driver portion of the inhibitor or altering the intrinsic reactivity of the warhead toward target nucleophile by exploiting the multiscale simulations and analysing deeply computational data.

### Potential Supervisors

Alessio Lodola, Silvia Rivara, Marco Mor.

### Doctoral candidate's desirable skills and competences

#### **Scientific and technical skills**

Basic knowledge of medicinal chemistry, physical chemistry, informatics

Interest in Computer-Aided Drug Design (CADD)

#### **Other skills**

High motivation and Commitment to work in a competitive environment.

## Description of the research group(s) in which the doctoral candidate will be integrated

The Drug Design and Discovery group at the University of Parma (<https://saf.unipr.it/node/1323>) is interested in the field of drug design, synthesis of new chemical entities, study of the relationships between chemical structure and biological activity, and elucidation, at a molecular level, of the mechanism of action of drugs. The group is also interested in the qualitative and quantitative analysis of substances having biological activity, as well as medicinal products and their metabolites. Current Research in Drug Design and Discovery group includes: - Application of computational chemistry to drug design - Elucidation of the mechanism of action of medicinal agents through multiscale simulations and mass-spectrometry - Synthesis of new organic medicinal products - Targeted and untargeted metabolomics, mainly related to lipid signals. Multivariate analysis of omics data from complex biological matrices for the prediction of phenotypic responses.

Qualitative and quantitative analysis of drugs and related products (Physicochemical and In vitro PK characterization of new drugs). Areas of expertise of the group relevant for the proposal are: Computer-Aided Drug Design, Multiscale Simulations (including hybrid QM/MM methods), Enhanced Sampling approaches (umbrella sampling, metadynamics, steered-MD) Cheminformatics and Chemometrics (including Machine learning approaches), Medicinal Chemistry, Pharmaceutical Analytical chemistry. Achievements of the group

- Discovery of the first covalent inhibitor (URB597) of Fatty Acid Amide Hydrolase (FAAH), a milestone in the study of pharmacological effects of FAAH inhibition, and elucidation of its mechanism of action at molecular level through computational and experimental approaches.
- Discovery of the first class of covalent inhibitor of N-acyl ethanolamine acid amidase (NAAA) active in vivo as anti-inflammatory agents. These compounds have been further optimized, leading to derivatives with improved stability and drug-like profile. More recently, we have characterized the mechanism of action of this unique acid amidase and elucidated the SAR of NAAA substrates thanks to multiscale simulations.
- Discovery of the first class of covalent allosteric modulators of MAGL enzyme that functionally mimic sulfenylation of regulatory cysteines and act as neuroprotective agents in vivo.
- Design of new EGFR covalent inhibitors targeting the catalytic Lys745 active on C797S mutant resistant to the third-generation drug osimertinib
- Discovery of the first EphA2 receptor antagonist active on glioblastoma in vivo driven by Computer-Aided Drug Design approaches

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The Department of Food and Drug of UNIPR offers adequate space and infrastructures for running multiscale simulations and exploiting the results obtained from calculations through medicinal chemistry lab. 4 HPC Workstations mounting Nvidia GPU cards are available in the research group lab. The Drug Design and Discovery group has access to the HPC resources of UNIPR (<https://www.hpc.unipr.it/>), which allows to

massively parallelize simulations both on CPU and GPU architectures. The group has currently access to the resources of CINECA supercomputing facility. Specialized software for statistical analysis and multiscale simulations (i.e., AMBER, GROMACS, SCHRODINGER, GAUSSIAN) are available in the group.

### Collaboration networks involving the research team

The current project will be benefit of a network of international collaboration involving Prof. Adrian Mulholland (University of Bristol, Bristol, UK), Prof. Vicent Moliner (University Jaume I, Castellon del Plana, Spain). Prof. Daniele Piomelli (University of California, Irvine, USA) and Chiesi Farmaceutici (Dr. Andrea Rizzi).

### International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- Exploiting the EndoCannabinoid System to control inflammation and promote neuroprotection and myelin repair (ExECS); PI: Marco Mor; "PRIN - 2017"; period 2019-2022.
- A computational platform for drug design using multiscale simulations and machine learning;  
- PI: Alessio Lodola; "Bando POR FSE 2014/2020 ER"; period 2021-2024.
- Targeting NAAA for non-addictive analgesic therapy; PI: Daniele Piomelli, co-PI: Marco Mor;"NIH-R01"; period 2023-2028.
- Allosteric control of monoacylglyceride lipase (MGL) activity; PI: Daniele Piomelli, co-PI: Marco Mor; "NIH-R21"; period 2022-2024.

## Doctoral Position

### **Illuminating dark gene targets in the human genome through big data analysis**

## Doctoral Programme

Biotechnology and Biosciences

## Description of the doctoral position's main topic

Over five thousand genes in the human genome have no or minimal functional information. Bioinformatics and Big Data analysis can accelerate the process of unravelling the biological roles of these unknown targets. The doctoral research will focus on genes, mRNAs, and proteins with unknown functions in human diseases of both genetic and non-genetic origin. The term 'unknown' pertains to targets lacking information regarding their function, interacting molecules, and potential drugs. As per the categorization established by the pharos database, these gene targets are designated as 'Tdark' (<https://pharos.nih.gov/>). PhD candidates involved in this project are expected to contribute to the development of bioinformatics methods for gaining insights on TDark genes. To this end, they will leverage cutting-edge technology and multiple data sources to accelerate the discovery of the genes' biological roles and their involvement in diseases. The emphasis will be on employing bioinformatics tools for functional gene association via comparative genomics and coevolutionary analysis (PMID: 37126713, PMID: 34753957) along with the integration of machine learning and AI methods to analyse sequences and structures. A comprehensive multi-omics strategy will be adopted to tackle Big Data, encompassing the exploitation of genome-phenome data to pinpoint variants and genes associated with undiagnosed diseases. The ultimate objective is to advance our understanding of human biology through foundational research, with the potential to translate findings into practical applications for diagnosing, treating, and preventing diseases.

The research outlined in our PhD program holds significant relevance within regional, national, and international contexts, offering valuable career opportunities. Upon completion of the PhD project, graduates will be well-equipped with expertise in bioinformatics, molecular biology, and data analysis, positioning them for various career paths. Potential opportunities include academic research positions, roles in biotech and pharmaceutical companies focused on drug discovery and development, and positions in healthcare institutions specializing in genomic medicine and personalized therapies.

## Sub-themes of the doctoral position's main topic (if any)

None



## Potential Supervisors

Riccardo Percudani, Cristian Capelli, Barbara Montanini, Roberto Ferrari

## Doctoral candidate's desirable skills and competences

### ***Scientific and technical skills***

PhD candidates involved in this program should have a solid understanding in the molecular aspects of biology and expertise in bioinformatics and Big Data analysis. Proficiency in programming languages for bioinformatics such as, e.g. Python, R, and C++ is also a desired requirement. Familiarity with machine learning and AI techniques is a plus. Knowledge of collaborative software platforms (e.g. GitHub) and data deployment according to FAIR principles would also be considered advantageous. Additionally, a keen interest in the scientific discovery, particularly of the function and evolution of human genes is essential for success in this project.

## Description of the research group(s) in which the doctoral candidate will be integrated

The protein function prediction group (unit1) is engaged in research at the intersection of Bioinformatics and Biochemistry, with a primary focus on developing computational methods for predicting the function of uncharacterized genes and subsequently validating these predictions through experiments. The core competency of our laboratory is the molecular identification of enzymes and metabolic pathways, harnessing the power of Big Data analysis of protein structure and evolution to uncover biological functions (PMID: 37043529, PMID: 32601391, PPR: PPR727037). The human genetics group (unit2) focuses on the investigation of the evolutionary dynamics shaping the distribution of genetic variation in human and non-human primates. We explore within species population structure to identify genetic variants differently distributed across groups predicted to have strong phenotypic impacts (PMID: 37105174, PMID: 36191217, PMID: 32690317). The transcriptomics group (unit3) is involved in In vivo-BRET drug discovery platform for the identification of protein-protein interaction inhibitors of biomedical interest, and in Transcriptome profiling of pre-clinical models of human diseases (PMID: 32001678, PMID: 36290107, PMID: 37730279). The Molecular Cell Biology of the Epigenome group (unit4) is engaged in Epigenomics and genome editing, CRISPR-Cas screenings in cancer and respiratory organoids models, and in investigating the Role of transcription factors and ncRNA and in genome structure and expression (PMID: 31759822, PMID: 30552103, PMID: 31373033)

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The doctoral program will take place at the University of Parma (UNIPR) campus, a contemporary centre for research dedicated to fostering scientific discovery and cooperation. The doctoral student will have free

access to the UNIPR High Performance Computing (HPC) cluster ([www.hpc.unipr.it](http://www.hpc.unipr.it)), which features cutting-edge CPU and GPU nodes. Additionally, a dedicated node with priority reservation for the protein functional prediction group will be available. Working within an interdisciplinary setting, the candidate will collaborate closely with fellow researchers across both dry and wet laboratories. Units involved in the project provide laboratory spaces equipped with essential molecular and cell biology apparatus, including cell culture room, cold room, sterile hoods, FPLC, spectrophotometers, incubators, centrifuges, gel apparatus, PCR thermal cyclers, and other fundamental equipment for biochemistry and molecular biology experiments. Additionally, major equipment such as NMR, Mass Spectroscopy, CD Spectroscopy, AFM, Fluorescent microscopy are accessible at the campus core facilities and services.

### Collaboration networks involving the research team

The University of Parma belongs to the International Alliance EU GREEN (European University alliance for sustainability: responsible Growth, inclusive Education and Environment, <https://eugreenalliance.eu>). The cooperation between 9 Institutions provides opportunities for exchange and mobility of young researchers and students, offering matchmaking possibilities, Summer Schools, Blended Intensive Programmes, courses and joint research projects. The PhD Council in EU GREEN is working on developing new activities and harmonisation of practices across the universities. The activities in the clusters are leading to the development of research & innovation projects and Marie Curie Exchange projects, which will be amenable to PhD mobility in a multidisciplinary environment. Of particular interest will be the Cluster on “Emerging paradigms for health and wellbeing” with the subgroup on “Personalized/precision medicine and care / nanomedicine”.

The PI of the protein function prediction group (RP) is involved in ELIXIR as a delegate to the Italian assembly and coordinator of the Rare Disease community. Elixir is a European life sciences infrastructure, bringing together scientists from twenty-three countries. The infrastructure empowers researchers to access and analyse life science data, enhancing the significance and influence of life science research on public health, the environment and the economy. In the new Scientific Programme for 2024 to 2028, cellular and molecular research along with Human data and translational research are priority scientific areas, aligning closely with the focus of this doctoral program.

### International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

Riccardo Percudani is coordinator of the national project 2022-2024 “Actin-resistant acidic DNase for the treatment of CF pulmonary symptoms”, granted by the Cystic Fibrosis Foundation. He was previously head of unit in the project 2017-2023 “Protein Bioinformatics for Human Health”, Funded by the Italian Ministry

for Education. Cristian Capelli was awarded the 2021-2022 EASI Genomics (European Consortium) “Mind the GAP: comparing genotypes and phenotypes in assigning specimen to species-insights from Papio” and the 2021-2022 Leakey Foundation (USA) “The Y chromosome evolutionary history of Papio” projects. Barbara Montanini is Co-PI in the 2021-2024 project “ORGAN-ON-A-CHIP: organoidi personalizzati per lo studio in-vitro delle patologie (cardiache) trasmissibili”, Young Independent Research Group – YIRG, Università degli studi di Parma. Roberto Ferrari is involved as PI in the national AIRC 2023-2027 Grant "A CRISPR-Cas9 Screening of Highly Accessible Genomic Enhancers to Uncover Novel Hormone-Sensitive Cancer Vulnerability.

Implementation of artificial intelligence algorithms in the sonographic assessment  
of fetal anatomy

## Doctoral Position

### **Implementation of artificial intelligence algorithms in the sonographic assessment of fetal anatomy**

## Doctoral Programme

Translational Medical and Surgical Sciences

## Description of the doctoral position's main topic

The study proposal deals with an innovative research project involving AI and basic science applied to Obstetrics. We propose a research project aimed to develop an ultrasound-based DL-algorithm, which is capable to recognize brain structures and discriminate between normal and abnormal anatomy through a fully automatic data processing. This research project has been designed to develop a cross-disciplinary work in the field of obstetrical ultrasound paired with AI, which will involve a multidisciplinary team of Obstetricians, Fetal Medicine experts and Biomedical Engineers.

The main advantage of the implementation of a DL-algorithm for the automated basic assessment of the fetal brain is to objectify the ultrasound examination and reduce intra and inter operator variability. Another advantage of an AI-algorithm is the reduced time required to the examiner for the qualitative evaluation of the sonographic features of the fetal brain on the axial planes. This would optimize resources in terms of time required for the examination, improve efficiency of prenatal diagnosis and allow more time to communicate the results with the patients. Therefore, AI can enhance not only professional, but also patient's satisfaction (1).

The development of a specific AI-algorithm to recognize ultrasound patterns of normal anatomy could find further application in the field of ultrasound training, helping the non-experienced operators to identify the normal fetal CNS landmarks on the axial scanning planes. This approach is thought to flag the cases with abnormal or unusual brain findings which will be eventually sent for a targeted neurosonography performed by an expert.

The use of ultrasound screening tools should be simple, efficient and fast, especially for non-expert operators. The addition of an AI-based algorithm, which could differentiate between a normal or abnormal sonographic scan, might meet all of these criteria and have a place in the prenatal diagnosis daily practice.

The principal research project's objective is to validate a novel AI-based technology, which could potentially be used as a screening tool for fetal abnormal findings. A high-sensitive screening tool would also be cost-

effective, because it could be integrated in the regular antenatal care performed by non-fetal medicine experts, hence less expensive but maintaining almost the same low false-negative rate (22). The AI-algorithm would be able to detect unusual brain findings and thus, signaling cases which could benefit from an advanced multiplanar neurosonography performed by an expert. Moreover, the AI-algorithm is aimed at improving the performance of the standard antenatal screening of the fetal brain ensuring its reliable sonographic assessment within a shorter time of execution. Greater repeatability and reproducibility is to be expected, allowing to implement the US screening also in terms of efficiency on a vast scale, optimizing healthcare resources.

The fetal brain ultrasound evaluation is often challenging, requiring not only technical skills, but also specific knowledge of the fetal brain anatomy. The assistance of the AI during ultrasound examination is likely to have a major impact on the everyday clinical practice as it has the potential to also assist non-experienced operators, during prenatal ultrasound. Moreover, it could enhance the capability of the operator to recognize sonographic landmarks and could be easily integrated in dedicated teaching programs.

According to these considerations, the use of AI applied to ultrasound screening tools may provide high quality in the standard care.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Tullio GHI, Andrea Dall'Asta

### Doctoral candidate's desirable skills and competences

#### ***Scientific and technical skills***

The candidate will be required to have scientific and technical skills on the use of prenatal diagnosis of congenital anomalies and specifically CNS defects.

### Description of the research group(s) in which the doctoral candidate will be integrated

The research group in which the doctoral candidate will be integrated has an extensive knowledge and dedicated skills on expert assessment of fetal brain at antenatal ultrasound. Our group is considered among the leading teams in the prenatal diagnosis and classification of fetal brain anomalies with the use of dedicated and advanced neurosonographic imaging, including 2D and 3D ultrasound, fetal vascular tool, and automatic tools.

A link to the main publication on this topic from our research group is found at:  
<https://pubmed.ncbi.nlm.nih.gov/?term=ghi%20t%20and%20fetal%20brain%20ultrasound>.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

Ultrasound laboratories with high quality ultrasound machines, computers with dedicated software for images analysis and volume postprocessing.

## Collaboration networks involving the research team

The research team is connected with the following Centers from European and extra-European countries which will be part of a network for data collection and collaborative studies.

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

Call RF2021 (BANDO RICERCA FINALIZZATA 2021) Project code: GR-2021-12374064 - Artificial Intelligence algorithm for the screening of abnormal fetal brain findings at first trimester ultrasound scan. PI Alessandra Familiari (Gemelli Hospital Rome); DALL'ASTA ANDREA (Contributors. N. 1 University of Parma).

A Radio-immune-genomic Approach and Big Data Integration to Identify Predictive Signatures  
for the Response to Immunotherapy in Solid Tumors

## Doctoral Position

### **A Radio-immune-genomic Approach and Big Data Integration to Identify Predictive Signatures for the Response to Immunotherapy in Solid Tumors**

## Doctoral Programme

Translational Medical and Surgical Sciences

### Description of the doctoral position's main topic

Immune Checkpoint Inhibitors (ICIs) have prompted a paradigm shift in the treatment landscape of multiple cancer types achieving unprecedented results, although still in a limited subset of patients (ranging from 20 to 30%). Thus, the identification of patient- and tumor-specific biomarkers able to guide patient selection and clinical decision making is of paramount relevance. Current artificial intelligence (AI) models largely operate in the domain of a single modality, partly neglecting the overall clinical context, which inevitably reduces their potential. Integration of different data modalities may increase robustness and accuracy of prognostic and predictive models, bringing AI closer to clinical practice. AI approaches allow exploitation of high-dimension oncological data in research, being also capable of discovering novel patterns within and across modalities suitable for explaining differences in patient outcomes or treatment resistance. A large amount of biomarkers (genomic, epigenomic, transcriptomic, pathomic, immunomic, radiomic) related to IO's efficacy can be extracted with AI techniques across a wide variety of different cancer types, demonstrating the general applicability of the models.

The common theme of this project is based on the premise that tumor heterogeneity, and response to ICIs, can be untangled by a multidisciplinary strategy involving the integrated analysis of radiologic, immunophenotypic and genomic/transcriptomic clues.

In detail, the following research fields will be explored, with the ultimate aim to develop a multiomic profile endowed with the potential to provide a non-invasive approach to advanced cancer patients and predict the response to immunotherapy:

- Immunophenotypic analysis: definition of Tumor Immune Microenvironment (TIME) on tissue specimens; flow-cytometric analysis of peripheral blood immune cell subpopulations and ELISA immunoassay for soluble mediators at baseline and during treatment.
- Genomic and transcriptomic analysis: Next Generation Sequencing (NGS) and Nanostring technologies will be employed for molecular characterization using a DNA/RNA based assay.

- Radiomic analysis: Extraction of high throughput radiomic features from CT scans at baseline and during treatment.
- Bioinformatics analysis: AI methodologies (i.e. standard machine learning [ML] and deep learning [DL]), broadly divided into supervised (random forest, support vector machine), semisupervised (multiple-instance learning, graph convolutional network) and unsupervised (principal component analysis, k-means clustering) learning will be applied to our omics data.

In summary, our project aims to apply AI based analytic techniques in a standardized and nationally shared treatment setting for advanced cancers. The required cooperation between different professionals for obtaining an adequate development of the essential multimodal strategy leads to an overall improvement of assistance levels which translates in an enhanced delivered quality for the patients, perfectly integrating with the national healthcare system policy and with the purpose of the present Call.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Marcello Tiseo, Nicola Sverzellati, Giovanni Roti

### Doctoral candidate's desirable skills and competences

#### **Scientific and technical skills**

Specialization in Oncology or in Genetics is a plus, but not essential. Previous research experience is a plus.

#### **Soft skills**

The candidate should be able to work independently, take initiative, adopt critical judgment and demonstrate ability to work in team. In particular, he/she should be open to the multidisciplinary approach needed to realize this project. The project will include several network wide educational events and a secondment, for which travel, communication and social skills are required.

#### **Other skills**

Proficiency in written and spoken English is crucial. Knowledge of data analysis and statistics is essential.

### Description of the research group(s) in which the doctoral candidate will be integrated

Our project has been conceived drawing from a strong biological rationale, using innovative techniques to bridge the unmet need of predictive biomarkers of IO treatment efficacy in patients with advanced cancer. The availability of modern instruments and the recognized experience of the participating subjects in the field, clearly supply quality to the project and allow an easy transferability and applicability of the obtained



results to daily clinical practice. Multidisciplinary collaborative approach is a central issue for building personalized oncology and for devising novel treatments. Accordingly, the idea originating the COFUND research project 'Futuredata4EU' comes from the urgent need of exploring, innovating, integrating, and validating existing and novel approaches in a new objective unified framework for enabling in the current clinical practice, patient-specific methods and tools for the intervention and the follow-up of personalized therapeutic strategies. The involvement of several operative units and departments from different institutions in this project strengthens an already well-established cooperative attitude. Our project provides the opportunity to share innovative multiomic analysis of blood and tissue samples, high throughput extracted imaging features thus favouring the diffusion of the related knowledge. Medical Oncology core: responsible for interaction between clinicians and laboratory team; involvement in patient accrual and screening, obtaining informed consent, patient management and assessing treatment outcomes. Radiology and Bioinformatics core: the Radiology team will focus on CT evaluations and extraction of radiomic features. The bioinformatic team will support AI-based analyses of multiomic data. Histopathology core: responsible for diagnostic and immunohistochemical (IHC) analysis, assessment of patient immune profiles. Immunobiology core: responsible for characterization of circulating immune profiling based on Fluorescence Activated Cell Sorting (FACS) and ELISA analyses. Genetic-molecular core: responsible for development of genetic-molecular design of the project, interaction between laboratory team and clinicians and the management of biological samples.

### Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The project will take place at the Medical Oncology Unit of the University Hospital of Parma which is a high volume clinical centre, provided by Phase I and clinical research trial units with dedicated nurses, project managers and available laboratories. The research/diagnostic laboratory (CoreLAB) at the University Hospital of Parma contains the following technologies/expertise: nucleic acids extractor (MagCore HF16 Plus, RBC Bioscience Corp.), NGS Library Prep workstation (Hamilton MicroLab STARlet), quality control of nucleic acid and libraries (Agilent 4200 TapeStation System), Real Time PCR (Life Technologies, Roche), digital droplet PCR (Bio-Rad), NGS instruments (Illumina MiSeq and NextSeq550Dx) and Ella Automated Immunoassay System (Bio-Techne). At the Pathology Unit a MagCore HF16 Plus (RBC Bioscience Corp.), two NGS instruments (MiSeq, Illumina and IonS5, Life Technologies) and Nanostring technology are available. The platform available for FACS analysis is a Becton Dickinson FACSCelesta flow cytometer with BV configuration, specifically dedicated to translational studies. The system operates with BD FACSDiva™ software, a collection of easy-to-use tools for flow cytometer and application setup, data acquisition and data analysis. The Research and Innovation Unit provides methodological and biostatistical expertise, study quality assurance and control and management of financial aspects. The Ethics Committee Secretariat offers timely support to researchers, speeding up the submission process and ensure regulatory compliance. In the highly qualified

Unit, specifically trained personnel operate in compliance with Good Clinical Practice, by mean of Standard Operating Procedures. A team of biologists and bioinformaticians fully involved in research projects are available to embrace the PhD candidate and to support him/her.

### Collaboration networks involving the research team

To achieve the objectives of this project, a variety of techniques will be required. It is impossible for a single project leader to have in his/her laboratory the expertise necessary to perform complex interdisciplinary experiments. The increase in scientific interaction among the five cores of this project in the last four years has strengthened the goals of our current proposal, which are the foundation of the research planned here. Our ongoing funded projects have been mainly focused on the understanding of the mechanisms underlying inter- and intra-tumor heterogeneity and its impact on the clinical response to IO. The critical role played by genetic and immune pathways in cancer evolution and response to treatment and their non-invasive decoding by radiomics have helped us to formulate the new hypotheses of this COFUND research project. Most importantly, the funded research has prompted the group to raise new questions concerning the biology of the cancer-immunity cycle and its translation into clinical ground. During our frequent meetings in academic and clinical contexts, it became apparent to all of us that our common interest in optimizing the treatment of solid tumors, which increasingly affect the overall population, would have served our purposes better if our different but complementary expertise and objectives would have been combined in an integrated multidisciplinary research project. On the basis of recent results obtained in our laboratories, the five core leaders and associates were in agreement and felt rather strongly about the possibility to uncover the underpinnings of the heterogeneous response to IO by multiomic strategies. This novel approach was perceived as a crucial point of departure in the present investigation. It is conceivable that the future doctoral candidate would benefit not only from the high level of individual expertise on each field of the project but also from the strong motivation of the entire research group driven by the potential achievement of practice changing results. Moreover, acquiring the knowledge on AI based big data analysis represents an actual almost inevitable skill favouring the future integration of the candidate in academic or clinical environments.

### International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- PRIN Granted Project (P.I. Prof. Sebastiano Buti – 2 years) – “LINKing CHOLesterol hoMeostasis with immune-inflammatory profiles to predict immunotherapy efficacy in patients with metastatic renal cell carcinoma and non-small cell lung cancer: the LINCHOLM study”
- BANDO RICERCA FINALIZZATA 2021 (P.I. Prof. Marcello Tiseo, RF-2021-12374037 – 3 years

- “A Multiomic Approach to Identify Prognostic and Predictive Signatures in Advanced Non-Oncogene Addicted Non-Small Cell Lung Cancer (NSCLC) receiving Immunotherapy”
- University Granted Project (FIL-QI 2021, P.I. Prof. Marcello Tiseo – 2 years) – “Identification of Prognostic and Predictive Radio-Immune-Genomic Signatures in Small Cell Lung Cancer (SCLC) and Malignant Pleural Mesothelioma (MPM)”
- Region University Research Granted Project - FIN-RER 2020 - (P.I. Prof. Marcello Tiseo – 3 years) - “A multiomics approach to identify prognostic and predictive features of immunotherapy in solid tumors”
- AIRC Granted Project (P.I. Prof. Nicola Sverzellati, IG 2019, ID. 23606 - 5 years) - “A Radio-Immuno-Genomic Approach to Identify Prognostic and Predictive Models for the Response to Immunotherapy in NSCLC”.

### Doctoral Position

#### **Architecture: Critical Theory and Practice in the Age of AI**

### Doctoral Programme

#### Architecture and Design Cultures

### Description of the doctoral position's general/main topic

The doctoral research is about the transformation of Theory and practice in contemporary architecture culture under the influence of big data, parametricism, AI and computer simulations of all sorts. Traditionally architecture is a collaborative practice in which various agents such as clients and engineers, but also material, technology, economy and ecology are involved. However, today we witness a growing complexity in the interactions between architects, clients and – new to the field of architecture – the digital media that is increasingly dominated by artificial intelligence. By now the digital is less and lesser a tool to design spectacular buildings, as it was the case in the 1990ies when the computer was first introduced to the field of architecture. Instead, today with AI the digital media turns into an agent with a strong will of its own (Eigenwillen) which increasingly calls into question the role of the architect as a sovereign inventor of space, forms and figures. Already in the mid 1940ies the German philosopher Arnold Gehlen introduced the term resistance of things (Sachwiderstand). In this regard AI poses serious questions to the architectural practice and more so to the figure of the architect in its classical definition.

More and more the architect's role of being an effective figure of authority over the design process seems to turn into the role of managing the interrelations between the different and new actors (Bruno Latour). In such a complex interaction field classical architectural theory has to react and readjust its scope and methodology. Theory as establish over the last fifty years as critical theory or critical epistemology (Gleiter) needs to be extended and amended including artificial intelligence and digital media as major agents in the field of environmental design, that includes questions of territory, urbanity and architecture.

By analysing theory and practice in the age of AI this research attempts to open the discourse on the sovereignty of the architect over the architectural project. Additionally, the climate crisis, Co2 and resource crises are agents that enter the stage of architecture, city planning and heritage preservation. Hence, the main focus of this study is to investigate the complex interrelations between architecture, system earth and

AI and the central role that the architect takes as a mediator. These new agents require the re-thinking and re-conceptualization of the practice of the architect as a central figure in the reshaping of the endangered human life world. At issue is a global understanding of the future of the built environment.

In the preliminary phase, the research will analyse the historical emergence and evolution of the architect by referring to a selection of case studies and figures that has transformed the architectural panorama in the last decades. In the secondary phase report findings will play a key role in obtaining quantitative data about the status of the practice under the current emergence of AI and climate/computer simulation. In the third stage, the research will focus on comprehending the changes, potentials, and deficits of a more and more data and AI driven architectural practice.

### Sub-themes of the doctoral position's main topic (if any)

- Architecture and agency;
- Architecture between art, legislation, conservation and digital media;
- AI's threat to the sovereignty of architect as master builder;
- AI and the question of democratic space;
- Historical transformation of the profession of the architect since its emergence in the 15th century;
- Aesthetics of sustainability, futures and utopia;
- AI, ethics and memory;
- Post-Anthropocene and the concept of history.

### Potential Supervisors

Annalisa Trentin; Andrea Borsari; Joerg Gleiter

### Doctoral candidate's desirable skills and competences

#### ***Scientific and technical skills***

- Architectural Theory and Practice: A deep understanding of architectural principles, history, and contemporary practices is essential. This includes knowledge of design methodologies, construction techniques, architectural theory and aesthetics of architecture, design and city.
- Data Science Fundamentals: Proficiency in data science concepts such as data analysis, data visualization, statistical methods are crucial for handling large datasets.
- Spatial Analysis: Familiarity with spatial analysis tools and techniques is important for analyzing architectural data. Skills in Geographic Information Systems (GIS) and spatial data analysis can be particularly valuable.

- Research Methodologies: knowledge of research methodologies, including experimental design, data collection techniques, and qualitative and quantitative analysis methods, is necessary for conducting rigorous research in the field

### **Other skills**

- Data Ethics and Privacy: Awareness of ethical considerations surrounding data collection, usage, and privacy in architectural research is important.
- Visualization Techniques: Skills in data visualization techniques and tools can aid in effectively communicating insights derived from architectural data analysis to stakeholders.

## Description of the research group(s) in which the doctoral candidate will be integrated

### ARCHITECTURAL HUMANITIES GROUP

The topics of research are related to the fields of:

- History of architecture
- History of design
- Aesthetics of design and architecture
- Aesthetics of everyday life
- Philosophy and architecture
- Architecture and arts
- Architecture and literature, film, tv
- Urban and visual culture

### International Conferences: 2023

- Political models, imaginary and physical transformation of the Italian city from the post-World War II period to the present. Bologna 14-15 December 2023, curated by Giovanni Leoni, Andrea Borsari et al.
- The historical city. A critical Reference and Role Model for Innovative Urban and Metropolitan Development. Bologna 26-27 January 2023, curated by Giovanni Leoni, Andrea Borsari et al.
- Esthétique urbaine / Urban Aesthetologist. Aesthetics as a focus of disciplines on the study of city. Berlin, Centre Marc Bloch - Institute of Architecture at Technische Universität, 9-10 February 2023, curated by Andrea Borsari, Jörg Gleiter and Denis Thouard.
- Problems of Educational Organization for the Teaching of Urban Aesthetics. Paris, Faculté des Arts – Paris 1 – Sorbonne, 27 October 2023, curated by Stefano Ascari, Andrea Borsari and Antonella Tufano.

- - International Workshops Excesses of Memory? - University of Cambridge – Faculty of Modern and Medieval Languages and Linguistics, Gonville & Caius College - St John's College, Cambridge, 19 September 2022, Curated by Andrea Borsari, Giovanni Leoni and Robert Gordon.

ERC: SH5\_9 ARCHITECTURAL DESIGN GROUP.

The topics of research are related to the fields of:

- - Architectural design
- - Architectural composition
- - Theory of architectural design
- - Autonomy of architecture
- - Space, form and structure in architecture
- - Architecture and Landscape
- - Architecture and profession

ERC: SH5\_6; SH5\_8; SH2\_9; PE8\_3

International Conferences:

- - New European Bauhaus goes South - Bologna - THE MAIEUTICS OF THE CITY. November 30, 2021  
An international conference on architectural design in cities. Italian and foreign researchers discuss on the urban architectural transformations. Curated by Francesco Saverio Fera.
- - THE RECONSTRUCTION OF THE EUROPEAN CITY, International conference, May 6 and 13, 2022 - University Campus of Cesena; Scientific Committee: Lamberto Amistadi, Ildebrando Clemente, Antonio Esposito, Francesco Saverio Fera, Gino Malacarne, Annalisa Trentin.
- - THE POST-COLONIAL CITY. Case Studies from the Indian Subcontinent and the Middle East. International conference, April 18, 2023, University Campus of Cesena. Curated by Stefania Rössl.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The University of Bologna has a Multicampus structure, ensuring the opportunity to learn and promoting stable research activities throughout the region, aiming to improve the university community's operations and quality of life. The doctoral candidate can benefit from the facilities provided at the Cesena Campus and at the Department of Architecture in Bologna, Viale del Risorgimento 2. Doctoral candidates can use laboratories with cutting-edge equipment that integrate and assist the educational path as LaFo - Photography Laboratory, LaMo - Architectural Models Laboratory, LaMoViDA - Modeling and Digital Visualization Laboratory for Architecture, LaRAC - Laboratory for the Survey of Architecture and the City, CARTA - Laboratory for Cartography and CAD and finally, OFFLINE - Architectural Technology Study Workshop/Innovation and Energy Efficiency Laboratory (access allowed to professors, students, and

undergraduates of the DA subject to authorization by the technical staff). Study rooms are also available for doctoral candidates on Campus and in Bologna. The Bologna Library “Michelucci” and Cesena Campus Central Library "Leon Battista Alberti", presents a specific section dedicated to the disciplines of architecture, alongside the other sections dedicated to Biomedical, Electronic and Telecommunications Engineering, Computer Science. They provide teaching and research support to both the University of Bologna and walk-in users. It enhances the university's knowledge repository with a wide range of specialized services. The heritage of the central section in Cesena Campus includes 30,1350 documents on various supports 44 journals, and 604 periodical mastheads. The Central Library provides bibliographic information, a loan and interlibrary loan service, a document supply service, online consultation and user training services, and the purchase and processing of bibliographic equipment.

### Collaboration networks involving the research team

The Architectural Theory group at TU Berlin. The AT group at TU Berlin examines the constant as well as changing foundations of architecture. The central theme is the Critical Aesthetics of Sustainability. The AT group takes the current crisis phenomena as its starting point, explores them historically and develops new theoretical approaches for the future from there. In this sense, architectural theory is 1. a critical questioning of existing theories, methods and practices and 2. their re-evaluation against the background of current issues. The central themes are utopia and apocalypse, sustainability and AI, architecture between documentality and mediality, new typology and urban morphology and tectonics in the age of the post-Anthropocene.

The working group consists of Prof. Dr.-Ing. habil. Jörg H. Gleiter (head of the research group), 1 guest professor (currently from Yildirim University, Istanbul), 1 post-docs, 2 1/2 assistant professors, 1 student tutor, 1 secretary and 7 PhD students. The Department of Architectural Theory maintains various research collaborations with colleagues in European and non-European countries.

The Centre Saint Charles at the Ecole des Arts of the Université de Paris 1 Sorbonne on Architecture and Arts appliqués, Beneficiary Partner of “AestheCity.

Urban Aesthetics for Changing European Cities”, Doctoral Networks (DN)

Call: HORIZON-MSCA-2023-DN-01-01, submitted. Andrea Borsari, professeur invite, March 2024, course on Aesthetics of the City.

The Centre for Advanced Spatial Analysis (CASA) at the University College of London - Bartlett School, which develops information technology and data processing in the disciplines of space and the built environment. Partner of “AestheCity. Urban Aesthetics for Changing European Cities”, Doctoral Networks (DN)Call: HORIZON-MSCA-2023-DN-01-01, submitted, coordinated by Andrea Borsari.



International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- "SPEME - Questioning Traumatic Heritage: Spaces of Memory in Europe, Argentina, Colombia (<https://www.speme.eu/>), secondment of 7 researchers from DA Unibo in the three Partner University, 2019-2024. International Conferences:
- Procesos de Memoria en América Latina y el Caribe: Encrucijadas y Debates, National University of Bogotá 28-30 September 2022, Ponentes en Conversatorio Giovanni Leoni, Andrea Borsari
- UBA – Universidad de Buenos Aires, seminario internacional “Arte y Memoria. Cruces entre género, generaciones y espacialidad en registros sensibles sobre pasados traumáticos”, Centro Cultural Paco Urondo, 21-22 March 2023.
- ROCK - Regeneration and Optimisation of Cultural heritage in creative and Knowledge cities, Climate - Greening the Economy in response to the call Cultural Heritage as a driver for sustainable growth, Horizon 2020 program (H2020-SC5-21, GA730280). ROCK works, among others, also on the city of Bologna, focusing the research-action on the University Area (called Zona-U) that revolves around the Zamboni axis and that is assumed as a cultural, creative, sustainable district. Ref. prof. Giovanni Leoni.
- BO2ND Bologna-Bogotá is an Innovative project within the framework of international cooperation agreements; in 2019 the Department of Architecture launched the BO2ND project: BOlogna-BOgotá collaborative projects. New forms of knowledge diffusion. Collaboration between the University of Bologna and the Universidad Nacional de Colombia in the field of architecture. Department of Architecture - Unibo - and the Facultad de Artes of the Universidad Nacional de Colombia - Unal - based in Bogotá. Ref. prof. Annalisa Trentin.
- VDM - Villes Minières du Maroc - INTERNATIONAL DEVELOPMENT COOPERATION PROJECTS OF DEPARTMENTS - CALL ""UNIBO - GLOBAL SOUTH"". General aim of the project is the study and produce a documentation of the most significant moroccan mining cities built by the OCP in the Phosphate Valley to define hypotheses for their valorization and eventual urban e architectural transformation. 04.2023 – 06.2024. Scientific head for the department prof.ssa Annalisa Trentin.

## Doctoral Position

### **Enhancing cultural heritage with generative AI and Big Data: New avenues for accessibility and engagement**

## Doctoral Programme

Arts, History, Society

## Description of the doctoral position's general/main topic

This doctoral project sits at the intersection of technological advancement in the fields of Artificial Intelligence and Big Data on the one hand, and the rich and diverse world of cultural heritage on the other. In recent years, the cultural sector has experienced an unprecedented digital transformation based on processes of digitization of assets and content. However, access to and interaction with these resources remains anchored in conventional cultural marketing methods, limiting the potential for a deeper, more personalized and inclusive experience. This project aims to explore and develop criteria and functions related to advanced recommendation engines, with a focus on the multimodal approach. This new orientation allows different types of content, such as text, images, music, and video, to be treated in an integrated and consistent manner. Such integration is key to providing an experience that reflects the complexity and diversity of cultural heritage, embracing its many expressions.

The idea is to use recommendation systems as new access channels through which users can discover and interact with cultural heritage in personalized ways. These systems, enriched by the latest innovations in AI, can make interaction with cultural heritage more intuitive, engaging and in line with users' individual preferences. The strength of the project lies in its ability to integrate the goals of the 'Culture, Creativity and Inclusive Society' area with the growing expertise in the Department of the Arts on the relationships between cultural heritage, the arts, data science and digital culture. A key component of this integration is the use of generative AI and Large Language Models, which are notable for their accessibility outside of high-tech contexts. These technologies, by their inherent nature, enable a democratic and participatory approach to advanced technologies in the cultural sector.

The goal of the project is to develop a model of an active, open, generative archive. Beginning with the analysis of archives and collections of museums and other public and private institutions, modes of intervention will be proposed such that cultural heritage is an entity in the making. In light of a renewed sensitivity in terms of inclusivity and intersectionality, the recommending systems whose development is

proposed here will stimulate reconsiderations, unexpected connections and empowering perspectives, enhancing the pluralistic nature of cultural heritage. Fundamental will be the involvement of artists, who will contribute to the exploration of alternative applications of AI and Big Data, as well as Extended Reality and social media-related technologies, based on interaction data between users and recommendation systems. By strengthening the role of culture as a vehicle for identification, innovation and public engagement, the project could serve as a model for future applications in other sectors such as education, tourism and beyond.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Gustavo Marfia, Guglielmo Pescatore, Francesco Spampinato

### Doctoral candidate's desirable skills and competences

#### **Scientific and technical skills**

“Data Science Expertise or Arts-Related Research Experience”: The candidate must possess either significant data science skills or a background in arts-related research using data-driven methodologies. This includes statistical analysis and machine learning competencies essential for the project.

“Adaptability and Motivation to Learn”: An eagerness to acquire any lacking skills in data science or arts-related research methodologies is crucial. Candidates should demonstrate a proactive approach to learning and adapting.

#### **Other skills**

“Machine Learning and Deep Learning Knowledge”: Understanding these technologies is beneficial for creating advanced recommendation systems and analysing cultural data.

“Interest in Cultural Heritage Fields”: While not required, interest or experience in cultural heritage, encompassing areas like Art and Fashion, Cinema, or Music Studies, is advantageous.

### Description of the research group(s) in which the doctoral candidate will be integrated

C.R.I.C.C. – Research Center for Interaction with Cultural and Creative Industries” works at the intersection of the regional production system and the economic development of the CCI sector by integrating research, digital and enabling technologies, creativity, and culture. A series of cross-disciplinary pilot projects develop new technological solutions to support the innovation of cultural and creative industries, with a focus on the field of audiovisual activities and digital applications to culture.

(<https://dar.unibo.it/en/research/research-projects/c-r-i-c-c-centro-di-ricerca-per-l-interazione-con-le-industrie-culturali-e-creative>).

“DASH – Data Analysis in Social Sciences and Humanities” is a departmental research group that promotes and enhances the development of cross-disciplinary collaborations through the application of data-driven methods. It is also interested in the collection and analysis of data archives, both textual and multimedia, through a new generation of tools that exploit computational methods for studying the dynamics of information in unstructured data, including artificial intelligence models such as machine and deep learning and Natural Language Processing.

“AVEC – Arts, Visuality and Electronic Culture” is an interdisciplinary Graduate Student Workshop that aims at mobilizing researchers, curators, artists, philosophers, and collectives in work-in-progress dialogues on the intersections between contemporary art, visual studies, and electronic culture. Live and in the Metaverse, AVEC offers a chance to reflect about our complex post-pandemic condition and the unstoppable process of confusion between the real and the virtual (<https://corsi.unibo.it/2cycle/arts-museology-curatorship/avec-arts-visibility-and-electronic-culture>).

“Narrative Ecosystems” is a research group focused on analysing narrative ecosystems, which are enduring, persistent, and shared worlds characterizing the current media landscape. This interest stems from observing the media's evolution since the mid-90s, marked by a proliferation of channels, platforms, and processes of remediation and relocation. The research outcomes are evident across various platforms: Media Mutations conferences, SERIES journal, projects like FARB's “Extended Narratives in TV Seriality” and Imperial's funded “Transmedia Storytelling in the Corporate Ecosystem.”

“VARLAB – The Virtual and Augmented Reality Lab”, whose lines of research focus both on the methodological aspects underlying extended reality technologies and on the creation of demonstrators and prototypes. Multiple verticalization projects linked to the creative cultural industries sector are active, aimed at creating both virtual reality and augmented reality systems to support archives and the arts. VARLAB also involves artists, curators, psychologists and educators with the aim of understanding the potential impact of extended reality technologies on learning and knowledge dissemination processes.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The Department of the Arts is organized across four buildings: Palazzo Marescotti, Complex of Santa Cristina, DAMSLab, Complex of via Azzo Gardino 23 and a Headquarters Organizational Unit (UOS) in Rimini (Palazzo Ruffi - Briolini). Palazzo Marescotti is the administrative headquarters (<https://dar.unibo.it/en/index.html>).

The reference library for teachers, researchers and students of the department is the "Biblioteca delle Arti" (<https://arti.sba.unibo.it/>)

VARLAB – Virtual and Augmented Reality Lab is a collaboration between the Department of the Arts and Computer Science aiming at designing and building distributed metaverse environments. The laboratory is

not only equipped with the most up-to-date equipment in terms of computing devices and head mounted displays for the development of extended reality scenarios, but also server resources that may be utilized to develop and run artificial intelligence paradigms, deep learning (<https://site.unibo.it/varlab/en>).

## Collaboration networks involving the research team

The three supervisors participate in the activities of the Alma Mater Research Institute for Human-Centered Artificial Intelligence (<https://centri.unibo.it/alma-ai/it>).

The three supervisors are involved in various ongoing projects and initiatives promoted within UNA Europa, an alliance of 11 European universities (<https://www.una-europa.eu/>).

Two of the supervisors (Professors Marfia and Spampinato) are also members of the admission board of the PhD program in Cultural Heritage in the Digital Ecosystem (<https://phd.unibo.it/chede/en>).

Two of the supervisors (Professors Marfia and Spampinato) are members of a working group mapping an ecosystem related to “Cultural and Creative Industries and Sectors (CCSI)” carried out by UNA Europa within the framework of the KIC CCSI promoted by EIT – European Institute of Innovation and Technology.

One supervisor (Prof. Pescatore) is Programme Committee member of the International joint conference on Artificial Intelligence IJCAI 2024, special track AI, Arts and Creativity (<https://ijcai24.org/>).

One supervisor (Prof. Marfia) is scientific coordinator of the Rimini unit of the industrial research center of the University of Bologna for information and communication technologies. Its mission is to promote technology transfer and support innovation for large, medium and small local businesses.

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

“NEAD – Narrative Ecosystem Analysis and Development” is a National Research Project (PRIN). PI Prof. Guglielmo Pescatore. The project explores TV seriality through modeling tools, qualitative/quantitative analytical practices, software and algorithms.

“E / Quality. Strategies for Meaningful Inclusion in Italian Cinema and Television” is a National Research Project (PRIN). PI Prof. Maria Grazia Fanchi, Co-PI Guglielmo Pescatore. The group focuses on analyzing narrative ecosystems, considering the proliferation of channels, platforms, and processes of remediation and relocation.

“UnaVEx – Una Europa Virtual Exchange in Higher Education” is an Erasmus+ project developed within UNA Europa. PI Prof. Francesco Spampinato. The project aims to develop a virtual exchange framework for sustainability education across a partnership of leading European and African higher education institutions.

“RADICI – Realizzazione di una infrastruttura di Aggregazione e Digitalizzazione di patrimoni per favorire l’Interazione con il settore delle Industrie culturali e creative” is a PR-FESR EMILIA ROMAGNA 2021-2027 project. PI for the Interdepartmental Center for Industrial Research on Information and Communication Technologies unit, Prof. Gustavo Marfia. The unit develops an advanced digital platform for the support of cultural heritage research and dissemination.

“ATLANTE - Archivi Tecnologici per la Liberazione, l’Accesso, la Navigazione e la Trasmissione dell’Eredità culturale” is a PR-FESR EMILIA ROMAGNA 2021-2027 project. PI for the CRICC unit, Prof. Gustavo Marfia. The unit will digitize material from the Pavarotti Foundation archive and develop an AR application to use this content in museum contexts.

“Skank Bloc Bologna: Alternative Art Spaces since 1977”, PI Francesco Spampinato, is the winner of the eleventh edition of the Italian Council (2022) competitive call issued by the Italian Ministry of Culture. The grant supports the publication of a book published by Mousse.

## Doctoral Position

### **Normative Reasoning and Fairness in Explainable AI for an Inclusive Society**

## Doctoral Programme

Law, Science and Technology

## Description of the doctoral position's general/main topic

The widespread adoption of artificial intelligence (AI) in various domains has brought to light the critical issue of algorithmic fairness, particularly when AI systems are tasked with making decisions that impact individuals or groups based on normative data. Explainable AI (XAI) has emerged as a promising tool to address these concerns by providing insights into how AI systems make decisions and identifying potential biases. However, applying XAI to normative data presents unique challenges, as normative data are context-dependent and evolving over time. The ability to reason about normative data and to translate complex normative concepts into logically sound models is crucial for developing XAI techniques that can effectively address fairness concerns in this domain. This PhD research aims to investigate the application of qualitative methods, such as logic, to enhance the explainability of AI systems in the context of normative data and fairness. The research will explore the development of novel XAI techniques that leverage logic to reason about normative concepts, identify and mitigate bias, evaluate fairness, and communicate insights to stakeholders.

Topics of particular interest are:

- Explainability and fairness of judicial decisions using judicial case-based reasoners that behave like binary classifiers with realistic assumptions (such as inconsistent case bases, knowledge incompleteness, etc.)
- A critical investigation of various forms of fairness and of normative explainability within formal argumentation frameworks with structured arguments
- Explaining legal conclusions in rule-based systems that incorporate deontic concepts
- Formal models to implement procedures of the AI Act, such as the fundamental right impact assessment
- Ethical implications of using XAI in normative domains and propose strategies for responsible AI development and deployment.

The project is organized in three main steps:

1. theoretical analysis and investigation on “Fairness in Explainable AI” model, criterion, principles;
2. Normative Reasoning model definition;
3. Evaluation of the model.

## Sub-themes of the doctoral position’s main topic (if any)

None

## Potential Supervisors

Antonino Rotolo; Réka Markovich; Emiliano Lorini

## Doctoral candidate’s desirable skills and competences

### **Scientific and technical skills**

- Good knowledge of Artificial Intelligence (AI) and Explainable AI (XAI)
- Familiarity with logic and formal reasoning methods
- Excellent analytical and problem-solving skills

### **Other skills**

- Knowledge of legal reasoning and argumentation frameworks
- Experience with deontic logic and normative concepts
- Programming skills (e.g., Python)

## Description of the research group(s) in which the doctoral candidate will be integrated

LAST-JD is an International PhD programme. The consortium is composed of 29 partners (9 beneficiaries, 2 research centres, 4 associated universities, 14 industries) with seven EU countries (Italy, Luxembourg, Lithuania, Spain, Austria, Germany, Belgium) and two non-EU countries (Australia, USA). The 9 universities are: University of Bologna (UNIBO), University of Turin (UNITO), University of Luxembourg (UNILUX), Universitat Autònoma de Barcelona (UAB), Mykolas Romeris University (MRU), KU Leuven (KUL), Leibniz Universität Hannover (LUH), Universität Wien (UNIVIE) and Universidad Politécnica de Madrid (UPM). All the said universities share framework co-tutelle agreements for the awarding of double degrees.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The University Library System offers collections of books, magazines, exam texts, databases on traditional and electronic media; and manages advanced bibliographic services, specialized for disciplinary fields, to support teaching and research. The System is divided into 27 libraries and over 75 access points with 6,000



reading places. The overall heritage consists of approximately 4,000,000 volumes of press, 43,000 paper periodicals, 43,000 online periodicals, 152,000 e-books, dictionaries and encyclopaedias, 500 databases, over 8000 theses from doctoral and degree courses, 80,000 teaching materials in digital format. Among the services available: online catalogues, consultation, loan local and inter-library, supply of documents, assistance and guidance in bibliographic research through tutorials and services online, digital library platforms for archiving and preserving digital documentation produced at the University. We have a room for the lectures and a room for the PhD candidates where they can share their knowledge with interdisciplinary discussions. Finally, we have the possibility to have the support of the cloud computing equipment from UNIBO data factory and CINECA.

## Collaboration networks involving the research team

“Law, Science and Technology” is an interdisciplinary international PhD programme that involves a network of about 20 universities in Europe and extra-EU (e.g., Stanford, University of Pittsburgh, La Trobe – Australia, etc.). It hosts MSCA-EJD PhD students. LAST-JD counts on more than 100 alumni who now are professors, assistants, and lecturers in different EU and extra-EU universities. Many are also playing an important role in AI agencies, government ICT and Law departments, or the LegalTech domain.

We have a strong connection with the AI community thanks to the PNRR project “Future Artificial Intelligence Research (FAIR)”.

We have a strong connection with CINECA thanks to the PNRR project on HPC (ICSC National Research Centre in High-Performance Computing, Big Data and Quantum Computing).

The topic of Explainable AI is fundamental for supporting trustworthy AI and guaranteeing democratic principles. This topic is connected to the following call for proposals in the Horizon Europe Plan.

We are in strict contact with:

IAAIL (International Association of Artificial Intelligence and Law)

CINECA (<https://www.cineca.it/en>)

IFAB (<https://www.ifabfoundation.org/>)

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- ERC CompuLaw, Giovanni Sartor, Computational Judiciary System
- ERC HypermodeLex, Monica Palmirani, eLigilsation and AI
- JUST, FACILEX, Giuseppe Contissa, eJustice

- CERV, FAST-LISA, Francesca Curi, Hate Speech and Human Rights
- PON, Digital Twins, Antonino Rotolo, Smart Cities

## Doctoral Position

### **Data Analytics and AI for supporting legislative assistance at WIPO: a neuro-symbolic approach**

## Doctoral Programme

Law, Science and Technology

## Description of the doctoral position's general/main topic

The project should analyse the data science and AI techniques for supporting the legislative assistance process in WIPO using normative documents, including Member States legislation, in order to extract legal knowledge, classify the main rules in selected areas of the patent law domain, monitoring the evolution of the domestic laws in this sector, identify common patterns and generate benchmark provisions to provide support to the legislative advice work carried out at WIPO. Prediction of future needs is another important goal for anticipating the assistance requested by Member States and enhancing the efficiency of delivering such services. The analysis of the big data (including data and documents and relationships between them) has the aim to detect, measure and address WIPO policies in the light of the Member States legislation to have more success in the regulative enforceability of the WIPO requirements.

The project includes three main steps:

1. analysis of the literature and the state of the art, using the data and documents collected from WIPO and Member States. Clean and harmonizing the data/document is fundamental for avoiding bias, distortion, and undesirable discrimination effects. Akoma Ntoso OASIS standard XML is used for harmonization and data cleaning.
2. Model development for elaborating the data using data science and AI models and techniques. In this step, several techniques will be compared using hybrid and neuro-symbolic approaches (symbolic, sub-symbolic, and knowledge graph representation).
3. Developing of dashboard for visualizing the results using metrics, indexes, and benchmarking techniques to explain the results.

The project includes a period at least of 12 months in WIPO premises for making experiments in place, tuning the model, to evaluating the results with the end-users.

## Sub-themes of the doctoral position's main topic (if any)

None

## Potential Supervisors

Monica Palmirani, Rodríguez Doncel Víctor, Bart Verheij.

## Doctoral candidate's desirable skills and competences

### ***Scientific and technical skills***

- Good knowledge of Artificial Intelligence (AI) and Explainable AI (XAI)
- Familiarity with logic and formal reasoning methods
- Excellent analytical and problem-solving skills

### ***Other skills***

- Knowledge of legal reasoning and argumentation frameworks
- Experience with deontic logic and normative concepts
- Programming skills (e.g., Python)

## Description of the research group(s) in which the doctoral candidate will be integrated

The group is composed by several other PhD candidates, researchers and network of full professors.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The University Library System offers collections of books, magazines, exam texts, databases on traditional and electronic media; and manages advanced bibliographic services, specialized for disciplinary fields, to support teaching and research. The System is divided into 27 libraries and over 75 access points with 6,000 reading places. The overall heritage consists of approximately 4,000,000 volumes of press, 43,000 paper periodicals, 43,000 online periodicals, 152,000 ebooks, dictionaries and encyclopaedias, 500 databases, over 8000 theses doctoral and degree courses, 80,000 teaching materials in digital format. Among the services available: online catalogues, consultation, loan local and inter-library, supply of documents, assistance and guidance in bibliographic research through tutorials and services online, digital library platforms for archiving and preserving digital documentation produced at the University. We have a room for the lectures and a room for the PhD candidates where they can share their knowledge with interdisciplinary discussions. Finally, we have the possibility to have the support of the cloud computing equipment from UNIBO data factory and CINECA.

## Collaboration networks involving the research team

“Law, Science and Technology” is an interdisciplinary international PhD programme that involves a network of about 20 universities in Europe and extra-EU (e.g., Stanford, University of Pittsburgh, La Trobe – Australia, etc.). It hosts MSCA-EJD PhD students.

We have a strong connection with the AI community thanks to the PNRR project “Future Artificial Intelligence Research (FAIR)”.

We have a strong connection with CINECA thanks to the PNRR project on HPC (ICSC National Research Centre in High-Performance Computing, Big Data and Quantum Computing).

The topic of IPR is fundamental for supporting the digital transformation of society, emerging technologies (e.g., AI), the global research. Good IPR management supports the EU economy to compete with a robust framework where the shareability of knowledge and protection of intellectual rights are balanced for fair growth. WIPO will be involved intensively in the project.

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- ERC CompuLaw, Giovanni Sartor, Computational Judiciary System
- ERC HypermodeLex, Monica Palmirani, eLigilsation and AI
- JUST, FACILEX, Giuseppe Contissa, eJustice
- CERV, FAST-LISA, Francesca Curi, Hate Speech and Human Rights
- PON, Digital Twins, Antonino Rotolo, Smart Cities

## Doctoral Position

### **Large Language Models for a personalised access to large cultural data**

## Doctoral Programme

Cultural Heritage in the Digital Ecosystem

### Description of the doctoral position's general/main topic

The massive and systematic digitization of cultural heritage has been considerable in the past decades and is greatly accelerating. These investments generate vast quantities of data (cultural big data), the processing and use of which require a radically different approach compared to the manual curation used in the past. Cultural big data poses a series of specific challenges: they contain multimodal collections, including texts and images, they are composed of complex objects, and they lend themselves to a great wealth of use cases. The rapid improvement of Artificial Intelligence (AI) technologies offers for the first time the concrete possibility of responding to this challenge, and of maintaining and strengthening the role of the University of Bologna, Emilia-Romagna, and Italy at the frontier of technologies digital applied to cultural heritage.

We propose a project focused on the research, development, and empirical evaluation of Artificial Intelligence methods to offer scalable and personalized access to cultural big data. Specifically, we will focus on Large Language Models (LLMs), as a novel and promising approach to this challenge. The project is based on three foundations: 1) scalability: the use and adaptation of innovative pre-trained foundation models suitable for very large collections; 2) personalization: the definition and empirical evaluation of user profiles to which various information needs correspond, and for which foundational models will be adapted (e.g., fine-tuning, instruction-tuning) and empirically tested in participatory studies; 3) open science: the project reuses public models and data as much as possible, and publishes all results (code, data) in open and FAIR modes.

The project should start by defining a set of profiles of use of cultural big data (e.g., general public, user, student, researcher, curator), which correspond to demanding specific information. A set of open and pre-trained Large Language Models will be selected and adapted to respond to each usage profile in interactive agent (chatbot) mode. Models of interest include Mistral, LLaMA, OpenLM, and others. Multimodal models will also be considered (e.g., working across text and image modalities). Model adaptation constitutes a key research component of the project, as several approaches will be tested including prompt engineering, instruction-tuning, fine-tuning, and Retrieval Augmented Generation. Some of these methods will require the development of new datasets that will be created semi-automatically and published openly. The

evaluation of the results will include the development of a Web interface and participatory sessions with users belonging to different usage profiles.

The candidates are encouraged to propose their own project ideas along these broad lines.

## Sub-themes of the doctoral position's main topic (if any)

None

## Potential Supervisors

Giovanni Colavizza, Silvio Peroni, Fabio Tamburini, Francesca Tomasi

## Doctoral candidate's desirable skills and competences

### **Scientific and technical skills**

- Solid foundations in digital humanities
- Foundations of informatics
- Solid programming and software development skills, ideally in Python
- Experience with relational databases, foundational data structures, and algorithms
- High-school level linear algebra, calculus, probability, and statistics
- Basics of machine learning theory and practice

### **Other skills**

- Solid foundations and practical experience with implementing machine learning solutions
- Experience with a machine learning framework, ideally PyTorch, and with mainstream machine learning Python libraries and resources
- Experience with either Natural Language Processing or Machine Vision (or both)
- Experience with Large Language Models (usage, prompting, tuning, deployment)
- Practical experience with data analysis methods
- Practical experience with big data processing (e.g., using distributed computing)
- Practical experience working with cultural heritage data

## Description of the research group(s) in which the doctoral candidate will be integrated

The doctoral candidate will be a member of the Digital Humanities Advanced Research Centre (/DH.arc), part of the Department of Classical Philology and Italian Studies (FICLIT), <https://centri.unibo.it/dharc/en>, that connects students, researchers, IT staff, and professors from FICLIT and the Department of Computer Science and Engineering (DISI) and affiliated structures, within the University of Bologna. The Centre supports scholars and institutions in designing, developing, and maintaining DH research projects. The aim is to be a hub for researchers and agencies currently working in the field of DH, and to promote innovative projects in

the Humanities. /DH.arc is a platform wherein to foster collaborations, exchange ideas, discuss approaches and experiences, and train for DH skills. The main covered research topics are: knowledge organization, knowledge representation, data science, semantic publishing, computational linguistics, digital philology (<https://centri.unibo.it/dharc/en/research/topics>). The projects' portfolio includes all the works that are somehow related to the /DH.arc centre, including projects born and maintained at the /DH.arc centre, projects inherited from prior centres (e.g. Multimedia Centre CRR-MM), or projects born in a different context that are led by /DH.arc members (<https://centri.unibo.it/dharc/en/research/projects-at-dh-arc>).

For the whole set of activities (including, with the research centre, a couple of educational programmes and research outputs) see also BoldH, the Bologna Digital Humanities Hub: <https://dharc-org.github.io/boldh>.

### Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The doctoral candidate will have at his/her disposal: together with the FICLIT spaces (library and reading rooms for 312 people, <https://bur.sba.unibo.it/>) a room devoted to PhD students (8 PC, 1 scanner and a laser print) with access to online resources (through AlmaRE, <https://sba.unibo.it/en/almare/almare>) and the ADLab centre for digitalization (<https://site.unibo.it/adlab/it>).

See: <https://ficlit.unibo.it/it/ricerca/laboratori-di-ricerca>

As far as the /DH.arc infrastructure is concerned, the environment for the PhD candidate is based on:

- Resources for computing and storage
- Server Dell PowerEdge R740xd for virtual machines devoted to research projects
- Server Dell PowerEdge R7425 for hosting of applications and institutional websites
- Server DELL PowerEdge R7525 with GPU AMD MI250 for ML and AI applications
- Storage 200TB

Software platforms

- Omeka S for Digital Library and virtual exhibitions
- ResearchSpace for the development of full scholarly research activities
- CLEF for the creation of a digital collection
- Pytorch for ML applications

### Collaboration networks involving the research team

The /DH.arc center has several partnerships at national and international levels with DH associations (AIUCD, EADH, and ADHO), and with international infrastructures (e.g. DARIAH and OpenCitations).



The project involves collaborations with the State Archives of Bologna, the National Archives System, the University Digital Library, and the publisher Il Mulino. At the level of the University of Bologna, the project involves the scientific committee of the /DH.arc (Digital Humanities Advanced Research Center) of the Department, which since 2018 has been working on cultural heritage data processing systems, carries out a series of projects and has an adequate IT infrastructure for project management.

Colavizza collaborates with a variety of international organizations in his research, including the Wikimedia Foundation, the EPFL, and the University of Amsterdam. He is a visiting fellow at the Alan Turing Institute (UK) and the Centre for Science and Technology Studies, Leiden University (NL).

### International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- Polifonia H2020, <https://polifonia-project.eu/>- 2021-2024 - Researcher Marilena Daquino (Team member) – output for DH.arc: Melody + CLEF + musoW (See: <https://centri.unibo.it/dharc/en/research/projects-at-dh-arc>)
- Spice H2020 (Social cohesion, Participation, and Inclusion through Cultural Engagement), <https://cordis.europa.eu/project/id/870811> - 2020-2023 – Silvio Peroni (PI) + DH.arc members
- MiC - Partenariato Esteso 5 'Changes: Cultural Heritage Active Innovation For Next-Gen Sustainable Society' – Spoke 4 – 2022-2025 - Silvio Peroni (Leader) + DH.arc members
- MiC - National Digital Library agreement for DL pilot project (national funds) – 2022-2025 – Francesca Tomasi (PI) + DH.arc members
- MiC - Bando Cultura (national project), <https://site.unibo.it/ficlit-fondo-cultura/it>, 2021-2025 – Francesca Tomasi (PI) + DH.arc members
- ERC HyperModeLex <https://site.unibo.it/hypermodelex/en> PI: Monica Palmirani, Univ. Bologna, member Fabio Tamburini. Sviluppo di LLM per il linguaggio giuridico
- PRIN2022 ReMind, PI: Vito Pirrelli, ILC-CNR, pisa, member Fabio Tamburini. Sviluppo e utilizzazione di LLM per il linguaggio patologico
- Dutch Research Council (NWO), “HAICu: digital Humanities - Artificial Intelligence - Cultural heritage”. Giovanni Colavizza (Co-I). <https://www.haicu.science>

## Doctoral Position

### **Generative Artificial Intelligence and Creativity**

## Doctoral Programme

Data Science and Computation

### Description of the doctoral position's general/main topic

The project aims to investigate the generative capabilities of Artificial Intelligence, with a specific focus on its multimodal applications in enhancing creative human activities. By examining the synergy between Natural Language Processing (NLP) powered by Large Language Models (LLMs) and the advanced imaging techniques offered by Diffusion Models, the project explores how these technologies can collaboratively support and amplify human creativity across various domains.

The research delves into the multimodal aspects of Generative AI, seeking to understand how textual and visual generative systems can interact to produce cohesive and innovative content. This includes assessing the capacity of LLMs to generate text that mimics human-like creativity and exploring how Diffusion Models can create images that are contextually relevant to textual inputs. Through practical experiments and prototypes, the project aims to showcase the potential/limitations of these technologies in real-world creative scenarios.

An integral part of the project is addressing the complex ethical, legal, and social implications (ELSI) associated with deploying AI in creative fields. This involves navigating copyright and intellectual property concerns, ensuring the authenticity of AI-generated works, and considering the impact on human creativity and employment. The research adopts an interdisciplinary approach, engaging with ethics, law, sociology, and the arts, to explore these challenges and opportunities.

Additionally, the project examines potential biases in AI models, their impact on generated content, and strategies to mitigate such biases. It also considers the democratising potential of AI in creativity, evaluating how these technologies can make high-quality creative tools more accessible, while also pondering the ethical responsibilities of AI developers and users.

Ultimately, the project aims to provide a comprehensive understanding of the multimodal applications of Generative AI in creativity. It seeks to pave the way for future research and development, advocating for the responsible integration of AI into creative processes and exploring how different modalities of AI can collaborate to enrich human creativity.

## Sub-themes of the doctoral position's main topic (if any)

None

## Potential Supervisors

Andrea Asperti, Maurizio Gabbrielli

## Doctoral candidate's desirable skills and competences

### ***Scientific and technical skills***

A doctoral candidate in "AI & Creativity" needs a mix of technical and creative skills, including:

- Programming in Python and familiarity with AI libraries.
- Machine Learning & Deep Learning: Understanding of algorithms and neural network architectures.
- Data Science: Skills in data manipulation, analysis, and statistical methods.
- Creativity in AI: Insights into computational creativity, generative models, and aesthetic evaluation.
- AI Ethics: Awareness of ethical use, copyright, and bias mitigation.
- Research Techniques: Proficiency in literature review, experiment design, and scholarly writing.
- Domain-Specific Knowledge: Depending on the research focus, expertise in related creative domains.
- Critical Thinking: Innovative problem-solving and analytical skills.
- Communication: Ability to convey complex ideas effectively to various audiences.
- Success in this field requires blending AI technical expertise with a deep understanding of creativity, ethical considerations, and continuous learning.

## Description of the research group(s) in which the doctoral candidate will be integrated

Andrea Asperti is an expert of deep learning and generative techniques. He and his research group have actively investigated the application of generative AI in a large variety of applicative domains, comprising conditional image generation, person re-identification, weather forecasting, and many others. He is particularly interested in the embedding process, that is the way the generative model learns to extract meaningful features and representation from the data, mapping them into a latent space. These representations are supposed to capture important characteristics of the data; different encodings may result in more or less entangled combinations of the different explanatory factors of variation behind the data. Interesting editing operations on data can be addressed following suitable trajectories in the latent space, allowing for tasks like altering specific attributes, domain adaptation and content or style transfer.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The candidate will have access to the research facilities of the DISI department, and the specific equipment of our research groups, comprising several workstations. In addition, if required, we shall prepare a dedicated Iscra project with Cineca to take advantage of the high-performance computing facilities of the Leonardo system.

## Collaboration networks involving the research team

The project is closely related to the “AI and Creativity” Summer School, which is one of the main actions of the UnaEuropa European Consortium for the period 2024-2027, coordinated by Prof. Andrea Asperti (DISI, and member of the Data Science and Computation PhD Board). Other directly involved universities include Paris 1 (Sorbonne), Dublin and Leiden. The Summer School aims to be a catalyst for interdisciplinary skills, both scientific and humanistic, necessary to operate in a world that increasingly requires integration with Artificial Intelligence for creative purposes. It will provide an important network of collaborations, within which the PhD candidate will find expert and multi-disciplinary connections, and in general a fertile ground for his/her research.

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

Andrea Asperti and his group are a component of the AI Research (FAIR) project of the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.3 funded from the European Union - NextGenerationEU, P.I. Michela Milano.

Unravelling the Evolution of Lithic Tools Morphology: Leveraging Big Data and Geometric Morphometrics in Archaeological Analysis

## Doctoral Position

### **Unravelling the Evolution of Lithic Tools Morphology: Leveraging Big Data and Geometric Morphometrics in Archaeological Analysis**

## Doctoral Programme

Human Sciences

### Description of the doctoral position's general/main topic

The advent of big data has revolutionized various fields, including archaeology, by enabling the analysis of vast datasets to uncover hidden patterns and insights. In the realm of lithic analysis, geometric morphometrics offers a powerful approach to understanding the evolution of stone tool technology. Geometric morphometrics provides a framework for quantifying and analysing shape variation, allowing to explore the intricate morphological features of lithic instruments in unprecedented detail. By leveraging big data methodologies (statistical methodologies such as clustering and regression on larger datasets, aided by advanced tools), researchers can process large quantities of morphometric data collected from diverse archaeological sites, spanning vast temporal and geographical scales. This project will focus on the synergy between big data analytics and geometric morphometrics in unravelling the complexities of lithic tools (belonging to a specific chronological period or representing a ubiquitous cultural innovation), shedding light on ancient hominin behaviour, cognitive abilities, and technological innovations.

The project fits into an international context constituted by the network of research centers focusing on prehistory. 36 institutions across Europe, Asia, Africa, and the Americas are already connected through the International Erasmus Mundus Master in Quaternary and Prehistory, and the development of this theme would represent an advancement in research methodologies (that can then be applied in a broader context generally to all cultural artifacts) in the cultural interpretation, of prehistoric artifacts. At the national and regional levels, the project will strengthen collaborations between museums and universities through the implications for the museumization of lithic industries, which are often regarded as a non-speaking heritage and challenging to disseminate.

After conclusion, it opens a plethora of career opportunities for researchers specialized in merging cutting-edge technology with archaeology. Professionals adept in big data analytics, statistical methodologies, and geometric morphometrics are in high demand across academic, research, and industry sectors. Positions such as data scientists specializing in archaeology, research analysts focusing on cultural heritage, and specialists

in digital archaeology are just a few examples of the diverse career paths available. Additionally, there are opportunities for collaboration with museums, cultural heritage institutions, and government agencies involved in archaeological preservation and research. Furthermore, this project lays the groundwork for interdisciplinary collaborations, offering avenues for archaeologists to collaborate with experts in computer science, data engineering, and machine learning. Overall, the skills and insights gained provide a solid foundation for pursuing a rewarding career at the forefront of archaeological innovation and data-driven research.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Marta Arzarello, Marco Peresani, Federica Fontana.

### Doctoral candidate's desirable skills and competences

#### ***Scientific and technical skills***

The candidate must necessarily possess the following skills:

- experience in using geometric morphometrics for contour analysis;
- knowledge of the technological approach to the study of lithic industries;
- understanding of human and cultural evolution throughout the Paleolithic;
- knowledge of Quaternary chronology;
- knowledge of basic statistics.

The following additional skills may be considered useful for carrying out the research project:

- Knowledge of the software R Studio;
- knowledge of the software Past;
- expertise in generative AI;
- ability to perform 3D scanning;
- knowledge of the fundamentals of Python programming;
- proficiency in at least two languages besides English;
- ability to structure a scientific article.

### Description of the research group(s) in which the doctoral candidate will be integrated

The involved research group deals with interdisciplinary studies (with expertise in prehistoric archaeology, geology, palynology, human and vertebrate paleontology, radiometric dating, fossil DNA, cultural heritage management, museology and museography) on prehistory from its early phases up to the Neolithic. The

doctoral candidate will be integrated into an international research network that has been conducting interdisciplinary and joint research in the field of prehistoric archeology for more than 20 years.

The research group is based on the collaboration between the University of Ferrara (Italy), the Muséum national d'Histoire naturelle de Paris (France), the Universitat Rovira i Virgili (Spain), and the Instituto Politecnico de Tomar (Portugal). These partners include collaborations with associated partners from Asia, Africa and South America. The connection between these institutions was made definitively official in 2004 (the year in which the joint Erasmus Mundus Master in Quaternary and Prehistory financed by the EACEA was opened, still active) and to date has seen the joint development of numerous research and training projects (see point 17).

Concerning the study of lithic industries, specifically, the research group is seeking to develop an innovative methodology that goes beyond a techno-economic approach and allows highlighting cultural trends within a “phylogenetic” perspective. However, this approach requires the collection and processing of a large amount of data, which must necessarily come from extensive geographical areas. The research group conducts excavations in Europe, Africa, and Asia (excluding the Americas due to their relatively recent human habitation), which will facilitate the collection of the dataset regardless of the specific research project presented by the candidate. From a methodological point of view, the PhD candidate will be supported by a large group of researchers involved in the ERC project “Why late earliest occupation of Western Europe?”. In this context, indeed, new approaches for interpreting lithic assemblages are being explored, approaches that include cladistics and geometric morphometrics. The latter requires the definition of a specific methodological protocol because there are no landmarks on lithic industries, thus contour analyses are necessary, which can only be performed on 3D models. At the local level, at the University of Ferrara, the research group within the section of Prehistoric and Anthropological Sciences possesses all the necessary expertise, as its members span their expertise from the earliest European peopling to the latest Mesolithic hunter-gatherers. Additionally, the research group is conducting excavations at some of the key sites of utmost importance for defining the technical behaviors of Pleistocene Hominins: Pirro Nord, Grotta della Ciota Ciara, Riparo Tagliente, and Grotta di Fumane, to name a few of the most well-known ones.

### Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The environment in which the candidate will be welcomed will provide all the necessary equipment for conducting the research. At the Department of Humanities, the following equipment (already available) will be provided to the candidate:

- 3D workstation including a Breuckmann smartSCAN AICON 3D Systems that uses structured light technology. The smartSCAN 3D is versatile and perfect for use in various settings, making it particularly suitable for mobile or on-site applications. Its sensor setup enables scanning at

triangulation angles of 30°, 20°, and 10°. This configuration enables precise measurement of even the most intricate object areas and geometries with exceptional detail.

- Equipped laboratory for creating 3D models through photogrammetry
- DELL workstation for Data Sciences.
- Lithic technology laboratory for the creation of a possible comparative collection (if necessary, within the scope of the presented project) and equipped with an extensive lithotheque.
- Transmitted and reflected light microscopes (if the presented project also involves the use wear analysis or the analysis of raw material procurement areas).
- Office, access to all online bibliographic resources, and a specialized library on prehistory. During the foreign mobility, at the Muséum national d'Histoire naturelle de Paris, additional equipment will also be made available.
- A KONICA MINOLTA RANGE 7Scanner, a measurement stand, a rotary table (acquisition and data processing software: RangeViewer and Geomagic Wrap).
- A Faro Edge ArmScanner from Faro, consisting of a measurement arm and a FaroBlu TM non-contact scanner (Geomagic Wrap software). This scanner is provided through a partnership with the NGO Global Digital Heritage.
- Access to the Distributed System for Scientific Collections (DiSSCo).

## Collaboration networks involving the research team

The international network involving the research team has been partially described at point 12 and supported by the common projects listed at point 17.

The network of national collaborations underlying the research stems from partnerships with colleagues from various Italian universities where prehistoric studies are particularly developed: the "Sapienza" University of Rome for paleontological aspects, the University of Trento for geoarchaeology and the later phases of prehistory, the University of Modena and Reggio Emilia for paleoenvironmental studies, and the University of Benevento for studies on the mineralogical characterization of raw materials.

An important role will also be played by collaborations with prehistory museums with which the team of researchers works closely and has curated part of the exhibitions: Borgosesia Paleontological Archaeological Museum, Pirro Nord Museum in Apricena, Civic Museums of Modena, Vittorino Cazzetta Museum in Selva di Cadore, Sant'Anna d'Alfaedo Paleontological and Prehistoric Museum, Isernia La Pineta Paleolithic Museum.

The collaborative network also includes some private companies that can contribute to the development of this research by providing their expertise in parallel but fundamental areas. The innovative company "Archeosmart s.r.l." (Italy), a spin-off of the University of Ferrara, will contribute to the dissemination of



results and their application in the context of museum outreach. The company "HolyMoka Games" (France) will contribute to the development of Python programming.

Moreover, the candidate will be integrated into a peer context thanks to the presence, within the PhD program in Human Sciences at the University of Ferrara, of other PhD students focusing on themes related to prehistory. Specifically, they will be accompanied by PhD students who apply geometric morphometrics to the study of the evolution of brain internal structures and by those studying the technological aspects of lithic industries.

### International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

The main projects in which members of the research group are involved are (non-exhaustive list due to character limitations):

- 610531-EPP-1-2019-1-IT-EPPKA1-JMD-MOB Erasmus+: Key Action 1 EMJMD. GA 2019-1462 International master in Quaternary and Prehistory - <https://quaternaryprehistory.eu/>- PI: Marta Arzarello
- ANR (Agence Nationale de la recherche) – AAPG2019 – ANR-19-CE27-0011. NEANDROOTS. Understanding a threshold in Human evolution at 450-350 Ka through the roots of Neanderthal behavior - <https://sites.google.com/unife.it/nenandroots/home> - PI: Marie-Hélène Moncel, involved members: Marta Arzarello
- 2023-1-FR01-KA220-HED-000153092 KA220-HED - Partenariats de coopération dans l'enseignement supérieur HERIT-AWARE « AWAREness and management of natural and cultural HERITage challenges: a skill acquired during university studies » - PI: François Sémah, MNHN - PI of the Ferrara' Research Unit: Marta Arzarello
- R2STAIR EH2020-MSCA-COFUND-2020 Programme, Grant agreement ID: 101034349 - <https://cordis.europa.eu/project/id/101034349> - PI: Carlos Lorenzo (URV), involved members: Marta Arzarello & Marco Peresani
- ERC Advanced Grant 2021 LATEUROPE - Why late earliest occupation of Western Europe? - <https://cordis.europa.eu/project/id/101052653> - PI: Marie-Hélène Moncel, involved members: Marta Arzarello & Paula Garcia Medrano
- Ecole Française de Rome « L'Italie paléolithique : peuplement et traditions techniques » - <https://www.efrome.it/it/la-ricerca/assi-di-ricerca> – PI : Marta Arzarello & Marco Peresani

- COST Project "Integrating Neandertal Legacy: From Past to Present" - <https://inealcost.inantro.hr/> - PI of the Ferrara Research Unit: Marco Peresani
- PRIN 2022 "AFTER THE ICE - Forager Uses of "Persistent Places" in the Late Upper Palaeolithic of the Circum-Adriatic Region: Perspectives from the Riparo Tagliente (Verona, Italy) and Badanj (Bosnia and Herzegovina)" – PI: Federica Fontana

## Doctoral Position

**Training academic language skills in the age of AI: Creating digital tools to help students write doctoral theses in English**

## Doctoral Programme

Doctoral School in Human Sciences: Linguistic and Literary Studies, History and Philosophy, Communication and Digital Culture

## Description of the doctoral position's general/main topic

The project, accommodating one PhD thesis, collocates in the area of digital tools development as aids for academic writing. Specifically, the idea is to use annotation tools based on AI to create searchable material to help students write their PhD theses in fluent English. On the background of English Medium Instruction, the academic-writing digital aids we will develop are aimed to provide both an online and a long-term learning instrument to facilitate scientific writing by non-native speakers of English.

The project plan is to collect data consisting of PhD theses produced in the regional context. With the development of increasingly international PhD programmes, theses in the English language are now quite spread, making it possible to produce corpora large enough to be representative of English academic language produced by non-native English speaking students in specialised domains of academic sciences (e.g. medicine, law, engineering, etc).

The data will be processed through computational linguistics methods and tools, and "big data" analysis techniques will be applied to corpora of language produced by the students. The corpora will then be used to identify the major linguistic gaps and to develop materials and activities to improve the skills required for academic writing of PhD theses. The skills under analysis through corpus work are of two types: a. general - involving understanding and production of English academic language; and b. specialised - i.e. inherent to a specific disciplinary field (e.g. medical, including sub-fields like e.g. gastroenterology, liver or kidney diseases and the like).

The project meets the Horizon social challenge of innovative and inclusive societies, associating it with the Emilia Romagna regional policies for research and innovation strategies supporting intelligent specialization and digital communication. In particular, the project aims to produce technologies which can be applied in the world of higher education, to improve both competence in the English language (the world's most spoken

language by non-natives) and digital competencies – two areas in which poor competence often means inequality of participation in the scientific debate.

The project is in collaboration with FEM (Future Education Modena), an international centre supporting research to improve the quality of education and the impact of education on social inclusion and improvement. FEM Research Centre is managed by “Wonderful Education”, a company promoting strategic research programs for education, training and teaching activities in the field of linguistics, with a special attention to innovative technological contexts for teaching and learning (EdTech). Wonderful Education is a partner company in this doctoral project.

### Sub-themes of the doctoral position’s main topic (if any)

None

### Potential Supervisors

Marina Bondi; Giuliana Diani; Silvia Cavalieri

### Doctoral candidate’s desirable skills and competences

#### ***Scientific and technical skills***

The candidate will have completed MA level studies in language sciences and will have basic knowledge of the field of discourse analysis and corpus linguistics, with experience in corpus compilation. Experience in academic discourse studies, genre analysis and the teaching/learning of languages for academic purposes is highly valued, but not mandatory.

### Description of the research group(s) in which the doctoral candidate will be integrated

The doctoral candidate will be working with the CLAVIER Group. CLAVIER (Corpus and Language Variation In English Research) is an interuniversity research centre founded in 2008 at the University of Modena and Reggio Emilia and is currently based there. Among the original members were the Universities of Modena and Reggio Emilia, Bergamo, Firenze, Milano, Modena and Reggio Emilia, Roma “La Sapienza”, Siena and Trieste. The Universities of Bari, Calabria, Pisa, Roma Tre, and Verona have since joined CLAVIER. The members of CLAVIER share a methodological framework that combines two complementary strands of linguistic investigation – corpus analysis and discourse analysis – to research on language variation in English, both in quantitative and qualitative terms. Thus, one of the main aims of CLAVIER is to contribute to an integration of quantitative and qualitative methods in research on language variation in terms of diachronic, geographic, and socio-cultural dimensions through the methodological tools offered by corpora. Particular attention is also given to the analysis of different genres and methodological registers.

(<https://clavier.fileli.unipi.it/>)

The Unimore research group works on language variation across several dimensions: disciplines, genres and local cultures. The researchers are engaged in the analysis of forms of two main areas: academic discourse – with a special emphasis on the humanities and the social sciences – and professional discourse – ranging from corporate to legal discourse. Special attention is paid to the role of language in knowledge dissemination and to the impact of new media on communicative genres. Textuality and phraseology are key interests. Recent studies centre on aspects of writer’s voice, attribution, discourse markers and evaluative language, as well as the key-words, key-phrases, lexico-semantic and lexico-grammatical features characterizing different discourses. A further area of investigation is the comparative analysis of dialogical features of academic writing and specialized media discourse in different settings and cultures. In a pedagogic perspective, the research group aims at building materials based on small and specialized corpora to exploit their potential for autonomous learning.

[\(https://clavier.fileli.unipi.it/research\\_units/universita-modena-reggio-emilia/\)](https://clavier.fileli.unipi.it/research_units/universita-modena-reggio-emilia/)

The research group also coordinates a reading group on academic discourse involving 6 PhD candidates working on different aspects of academic discourse.

### Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The doctoral candidate will have access to the facilities available to doctoral students at Unimore: library, office with laptops and other equipment for seminars, computer lab, virtual computers with software and corpora, research funds.

The PhD programme also offers a regular summer school on digital humanities and digital communication, with an excellent provision of lectures and workshops.

[\(https://www.summerschooldigitalhumanities.unimore.it/\)](https://www.summerschooldigitalhumanities.unimore.it/)

### Collaboration networks involving the research team

The international board of the PhD programme provides an excellent and stimulating network of high-profile international scholars in the field of academic discourse analysis (among others, Ken Hyland, Julien Longhi, Marcus Mueller, Josef Schmied)

The Unimore research team collaborates with:

- The full network of the national CLAVIER group (Verona, Milan, Bergamo, Trieste, Florence, Rome La Sapienza, Rome 3, Pisa, Bari, Calabria) (see above).
- A national group carrying out a national project on transparency (involving the universities of Rome La Sapienza, Verona, Calabria and Cagliari): Communicating transparency: New trends in English-language corporate and institutional disclosure practices in intercultural settings (Prot. 2020TJTA55):

the aim of this project is to investigate how transparency is reflected in the disclosure practices of corporations and institutions operating in international/intercultural contexts and thus using English to achieve this purpose.

- The Intermedi group at the University of Zaragoza (Spain) working on: SCIDIS (Visibility and dissemination of scientific research in digital communication) aiming to: identify the genres present in websites for international research projects / classify these digital genres, taking into account their communicative purpose / select and study those genres whose main objective is to give visibility to scientific output / determine their possible relation to other genres (e.g. genre chains, colonies, or constellations)

The group is in regular contact with centres such as the Centre for Corpus Research (Birmingham) and the Centre for Corpus Approaches to Social Science (Lancaster).

**International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year**

- 2017-2020 National project “Knowledge dissemination across media in English: Continuity and change in discourse strategies, ideologies, and epistemologies Ministero dell’Istruzione dell’Università e della Ricerca, PROGETTI DI RICERCA DI RILEVANTE INTERESSE NAZIONALE – Bando 2015 Prot. 2015TJ8ZAS. Principal Investigator Marina Bondi (national coordinator). Funding 450,000
- 2018-2022 National project for the national scheme “Department of excellence funding” 2018-2022. PI Marina Bondi, co-PI Laura Gavioli. Funding 5 million Euro
- 2022-2025 National project (PRIN) Communicating transparency: New trends in English-language corporate and institutional disclosure practices in intercultural settings (Prot. 2020TJTA55) National coordinator PI Belinda Crawford (University of Calabria). Modena unit coordinated by Prof. Marina Bondi Funding 360,000 Euro
- 2023-26 Visibility and dissemination of scientific research in digital communication. PI Rosa Loes Sanz, co-PI Pilar Mur Duenas Marina Bondi consultant.

## Doctoral Position

### **Big Data Analysis and Practical Reasoning for Religious Conflict Resolution**

## Doctoral Programme

Reggio Childhood Studies

## Description of the doctoral position's general/main topic

This research project represents a pioneering effort to integrate big data analytics of normative texts with practical reasoning methodologies to advance religious conflict mediation and resolution practices. By harnessing the power of data-driven insights and informed decision-making processes, the project aims to contribute to more inclusive, equitable, and peaceful societies characterized by respectful coexistence and dialogue among diverse religious communities. Furthermore, the project aims to contribute to more effective strategies for managing religious conflicts in diverse societal contexts.

This research project seeks to leverage big data analytics of normative texts and practical reasoning methodologies to enhance religious conflict mediation and resolution.

Its basic objectives are:

- To develop a comprehensive database of normative texts from various religious traditions, legal systems, and philosophical discourses.
- To apply big data analytics techniques, including text mining, sentiment analysis, and network analysis, to analyse patterns, norms, and principles relevant to religious conflict dynamics.
- To identify practical reasoning strategies and decision-making frameworks conducive to constructive dialogue, negotiation, and consensus-building in religious conflict mediation.
- To evaluate the effectiveness of data-driven approaches and practical reasoning methodologies in real-world religious conflict resolution scenarios.

The methodology is composite and includes:

- **Data Collection:** Compile a diverse corpus of normative texts, including religious scriptures, legal documents, philosophical writings, and relevant literature on conflict resolution.
- **Data Processing:** Utilize natural language processing (NLP) tools to preprocess and clean the textual data, ensuring consistency and accuracy for subsequent analysis.

- Text Analysis: Apply big data analytics techniques to extract key themes, sentiments, and patterns from the normative texts, focusing on areas related to religious beliefs, values, and practices.
- Practical Reasoning Framework: Develop a general framework for practical reasoning in religious conflict mediation, drawing on insights from recent debates in meta-normativity and, in particular, from the Kantian constructivist approach to practical reasoning.
- Evaluation: Assess the effectiveness of data-driven approaches and practical reasoning methodologies in promoting constructive dialogue, fostering mutual understanding, and facilitating conflict resolution outcomes.

The research is expected to enhance our understanding of the role of normative texts and practical reasoning in shaping religious conflict dynamics and resolution processes.

It also carries methodological and practical implications. First, it will be a methodological advancement insofar as the combination of big data analysis of normative texts and practical reasoning in conflict resolution contexts is highly innovative.

Second, it may provide the rational grounds for practical recommendations and guidelines for religious conflict mediators, policymakers, and stakeholders to facilitate more effective and sustainable conflict resolution strategies.

Finally, it certainly contributes to Knowledge Sharing, as it aims to foster interdisciplinary dialogue and knowledge exchange among scholars, practitioners, and stakeholders involved in religious conflict mediation and resolution efforts.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Carla Bagnoli, Alberto Melloni, Massimo Neri, Vincenzo Pacillo.

### Doctoral candidate's desirable skills and competences

#### ***Scientific and technical skills***

- Data Management: Proficiency in managing large-scale datasets, including data collection, storage, cleaning, and integration. Knowledge of database systems and data warehousing techniques.
- Data Analysis: Strong skills in data analysis using statistical methods and machine learning algorithms. Experience with data mining, text analytics, and sentiment analysis for extracting insights from unstructured data sources.



- Domain Knowledge: Understanding of religious studies, and conflict resolution theories to contextualize data analysis. Some familiarity with moral, social and political philosophy, to interpret data.
- Ethical Awareness of ethical and privacy issues related to handling sensitive data, especially in the context of religious conflicts. Adherence to ethical guidelines and data protection regulations.

Finally, the ability to collaborate with experts from diverse fields such as philosophy, political science, religious studies, and law. Programming and Software Development is useful.

### Description of the research group(s) in which the doctoral candidate will be integrated

The doctoral candidate will join an interdisciplinary group formed around the project "Conflict Resolution by Religious Authorities," funded by FAR-Interdisciplinare (awarded in November 2023). This project aims to establish a theoretical and practical framework for acknowledging the active role of interfaith dialogue in mediating conflicts, while adhering to the principles of fair democratic procedures and legitimacy constraints. Addressing this challenge requires an interdisciplinary approach, drawing upon resources and methodologies from philosophy (action theory, general and moral epistemology) and law (international and comparative law, canon law, and arbitration law). While existing philosophical and juridical studies concentrate on the objective sources of religious normativity, this project fills a significant gap by examining the relationship between objective sources of religious authority (traditions, norms, and normative practices) and subjective sources of religious authority (propositional and normative attitudes such as belief, hope, and faith). Attention to this relationship will uncover underexplored resources for structuring fair arbitration, rational negotiation, and explaining the emergence of new forms of shared agency driven by democratic values and committed to peace. The research team relies on an extensive international network, including the European Association of Religion.

The team's research focuses on three clusters of issues: 1. Elaborating the relevant conception of normative authority involved in arguments favouring the mediating role of religious institutions. 2. Exploring the voluntary dimension of membership in religious communities within conflictual contexts. 3. Assessing the impact of religious rights on the peace-building process by analysing social, cultural, and legal innovation processes involving religious groups and institutions as drivers and/or beneficiaries. The project provides an interdisciplinary framework for evaluating the arguments and normative practices that appeal to religious institutions in the democratic process of conflict resolution and peace-making. Research activities adhere to the highest standards of academic excellence and will result in articles published in specialized journals, one collective volume, and the organization of six seminars, one workshop, and one final international conference. Dissemination activities engage with the local community of policymakers, stakeholders, and the general public through clear and accessible presentations of research findings to promote dialogue on conflict resolution (CREA: <https://gratis-4815800.webadorsite.com/>).

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The project will be hosted at Department of Education and Human Sciences, which is home of the Interdepartmental Research Center “Observatory on Religious Freedom in the jurisprudence of the European Court of Human Rights” (ORFECT): <https://www.orfect.unimore.it/chi-siamo/>

ORFECT is an international network comprising over 40 scholars. It functions as an Interdepartmental Research Center within the University of Modena and Reggio Emilia, jointly led by the Department of Law, the Department of Education and Human Sciences, and the Department of Linguistic and Cultural Studies. The centre’s primary objective is to unite interdisciplinary expertise and knowledge pertaining to FoRB (Freedom of Religion or Belief).

ORFECT brings together European professors, researchers, and PhD students to cultivate interdisciplinary competencies and understanding of FoRB. It places particular emphasis on researching religious freedom within secular societies and exploring the intricate dynamics among religion, law, and politics. By focusing on key developments within the Council of Europe (CoE) and the European Court of Human Rights (ECtHR), ORFECT aims to foster international collaborative projects and forge successful university-industry partnerships.

The centre aims to establish itself as an academic and institutional focal point for European scholars, researchers, and doctoral candidates specializing in religious freedom, secular governance, and the interplay between politics and religion within Council of Europe member states. It seeks to align its research efforts with the jurisprudence of the European Court of Human Rights, particularly concerning cases impacting religious freedom and the relationship between politics and religion.

Specifically, ORFECT endeavours to promote research on ECtHR decisions pertaining to religious freedom, secular governance, and the interaction between politics and religion. It will analyse religious freedom cases brought before the Court, explore potential resolutions, and offer recommendations and opinions that may inform legal proceedings.

Finally, ORFECT is committed to fostering a culture of respect for religious freedom, non-discrimination, and equal opportunities through awareness and communication campaigns. It will organize and oversee conferences, seminars, legal clinics, and research and training initiatives focused on addressing disputes related to religious freedom and non-discrimination.

## Collaboration networks involving the research team

The international networks of ORFECT, the European Academy of Religion (EuARe)

In addition to the international networks of ORFECT, hosted at UNIMORE (<https://www.orfect.unimore.it/chi-siamo/>), here are the large international networks that may be involved:

- The European Academy of Religion <https://www.europeanacademyofreligion.org/it/aboutEuARE>, offers a platform for researchers and scholars to meet, exchange ideas, collaborate, and develop further research. EuARE is an independent association supporting the study, research, and collaboration of religious topics across disciplines at the intersection of religion and social, cultural, and political issues.
- The Gratianus Network. <https://www.jm.universite-paris-saclay.fr/formation/offre-de-formation/diplomes-duniversite/du-gratianus-etats-et-religions-en-europe/du-gratianus-states-and-religions-europe>. This is a European initiative aimed at delivering top-tier training to individuals interested in exploring the role of religion within the legal frameworks of European states and European Union law, including the European Convention on Human Rights (ECHR). This network is open to participants at the Master level or equivalent. The University Paris-Saclay serves as the lead institution for Gratianus and collaborates with various research institutes and universities under Erasmus agreements. These partners include the CNRS (Centre National de la Recherche Scientifique), EPHE (École Pratique des Hautes Études), Catholic Institute of Paris (ICP), as well as the Universities of Alcalá de Henares, Athens, Bonn, Complutense (Madrid), Florence, Modena and Reggio Emilia, Turin, Eastern Piedmont, and Vienna. Additionally, the Université Libre de Bruxelles and Cardiff University are also part of this collaborative network.
- ICLARS. [www.iclars.org](http://www.iclars.org). This is an international network comprising scholars and experts in the field of law and religion. Established in 2007, its primary objective is to serve as a platform for the exchange of information, data, and perspectives among members while also extending these resources to the wider academic community. From its inception, ICLARS has maintained an inclusive ethos, welcoming individuals with diverse political and religious affiliations who share an interest in the intersection of law and religion.

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

None

## Doctoral Position

### **Prevention and management of natural disasters through big data: EU law avenues**

## Doctoral Programme

European Law

## Description of the doctoral position's main topic

The use of data for the purpose of preventing and managing natural disasters is increasingly a priority at the European level. Clear evidence of this is the fact that the European Commission's Disaster Risk Management Knowledge Center has developed a full-fledged Risk Data Hub, i.e., a GIS platform that collects data on risk and methodologies for risk assessment (<https://drmkc.jrc.ec.europa.eu/risk-data-hub/#/>). Even earlier, the European Union had launched the Copernicus Program, which is able to provide, as part of the Union's spatial planning, a very significant amount of Earth observation data, often used to prevent and manage calamitous phenomena (<https://emergency.copernicus.eu>). And indeed, the increasing availability of big data is actually changing the way crisis management and humanitarian assistance operations can be developed.

This is true in general. However, this circumstance acquires special significance at the level of the European Union, given the fact that the latter has developed over the years the most sophisticated natural and man-made disaster management system internationally.

In recent years, the European Union has also given birth to a comprehensive data legislation, as part of a broader effort to constitutionalize the digital sphere, which has significant elements of interest in the area of disaster prevention and management.

The Data Governance Act (Regulation (EU) 2022/868), on the one hand, and the Data Act (Regulation (EU) 2023/2854), on the other, contain, in fact, provisions that have the potential to facilitate the use of -and access to -data for the purposes mentioned above. Specifically, the Data Governance Act prefigures the creation of European Data Spaces finalized, among other things, to develop more effective strategies in combating climate change and the increasing occurrence of emergencies. The Data Act provides for the possibility for public authorities (supranational and national) to access data generated by IoT systems to respond to public emergencies or other exceptional circumstances.

Taking the above into account, the Project proposed here intends to analyse how the supranational legal framework on data just mentioned is able to interact with the one already elaborated by the European Union for disaster management (starting with the EU Civil Protection Mechanism, Decision (EU) 1313/2013), highlighting possible shortcomings and problems and suggesting solutions and improvement strategies that can be activated by stakeholders and decision makers.

This Project is perfectly consistent with the scope of action of Cluster 3: Civil security for society of Horizon Europe. More specifically, it concerns the area of intervention Disaster-resilient societies.

### Sub-themes of the doctoral position's main topic (if any)

The main research strand of the Project concerns, as mentioned above, the analysis of the recent supranational data regulation and its application in relation to the disaster management mechanisms elaborated in the past by the Union.

Taking into account the possibility of involving the data centre of the European Centre for Medium Range Weather Forecasts, however, it is conceivable to have a specific (and additional) sub-strand of research looking at the interaction of the European Union's data regulation with its space policy, also in light of the very recent adoption by the European Commission and the High Representative of the Union for Foreign Affairs and Security Policy of a European Union Space Strategy for Security and Defense (JOIN(2023)9). In this last regard, of particular note is the intention, explicitly stated in the Strategy, to strengthen the Copernicus services, in order to create a true EU governmental service for Earth observation that can complement national infrastructures.

### Potential Supervisors

Federico Casolari, Mauro Gatti, Federico Ferri

### Doctoral candidate's desirable skills and competences

#### ***Scientific and technical skills***

Knowledge of EU law, with particular regard to its institutional dimension. A previous knowledge of both EU disaster law and EU data law could represent an asset.

### Description of the research group(s) in which the doctoral candidate will be integrated

The Project concerns the analysis of specific European Union regulations. So, it is per se inherent in the mission of the PhD Program in European Law. To this should be added that it intercepts the regulatory frameworks that the Union has developed and is developing to manage the digital transition and the environmental transition. These two processes and the reaction developed by the Union in relation to them are contributing to the affirmation of a doctrine of European strategic autonomy (or sovereignty) that is capable of profoundly changing the complex constitutional arrangements of the Union. They, therefore,

touch on profiles playing a central role in the development of studies and research on supranational law. Moreover, it is important to stress that these processes coincide with two thematic clusters of the Department of Legal Studies Project of Excellence “Law in Transition”). Therefore, there is also a full consistency between the activities of the Project and those of the Department proposing the Doctoral Program in European Law. As far as the research group is concerned, it should be noted that scholars participating in the Doctoral Program in European Law have gained significant experience over the years in EU disaster law and EU law in the digital environment. With regard to the first area, it should be mentioned the participation of members of the PhD Programme in a FIRB project and two PRINs (2017, 2020) in *subiecta materia*. One of the scholars is also a member of the Editorial Committee and the Yearbook of International Disaster Law (<https://brill.com/display/serial/YIDL>), for which he edits the European Observatory, co-director of the International Disaster Law Course organized in collaboration with the Institute of International Humanitarian Law of Sanremo, and PI of an AlmaCareS project for the development of active models of territorial resilience in Emilia-Romagna (SMART ER!). He is also coordinator of the UNIBO Thematic Group on Security. With reference to the second area, it should be noted that the coordinator of the Doctoral Program is a member of the SERICS (“Security and Rights in the Cyberspace”) Extended Partnership. Several members of the PhD Programme regularly research and publish on both the EU data protection framework and EU digital sovereignty. Finally, the presence in Bologna of the data centre of the European Centre for Medium Range Weather Forecasts (<https://www.ecmwf.int>) appears strategic too. In fact, it is intended to develop a structural cooperation with the centre, which will allow the PhD student(s) involved in the Project to be able to interact with actors who play a role of primary importance in the management of data relevant to disaster management. In this way, the solutions identified on the theoretical level will be able to be the subject of a technical-operational evaluation that will contribute to their consolidation.

## Description of the research group(s) in which the doctoral candidate will be integrated

For more detailed information about the group's research activities and achievements, additional details can be found on their respective web pages: <https://phd.unibo.it/dirittoeuropeo/en/people>.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

Doctoral candidates have access to the Law Library of the Department of Legal Studies and related databases (<https://giuridica.sba.unibo.it>). With more than 273,000 volumes, 2,900 journals and 90 databases, the Law Library is one of the most important at European level. They have also access to IT laboratories of the Department and computing resources of the Alma AI centre (<https://centri.unibo.it/alma-ai/en>).

## Collaboration networks involving the research team

The participation in the network operating the Yearbook of International Disaster Law may undoubtedly contribute to contacts and research opportunities for the PhD candidate(s). Also relevant in this respect will be the cooperation with the data centre of the European Centre for Medium Range Weather Forecasts.

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

### ***European Projects***

- Project "Fostering European Integration through Bachelor Education - SF2022-FIBRE", 2022 UNA Europa Call for Seed Funding - PI Federico Casolari - UNIBO research members involved in elaborating innovative teaching techniques combining international law with EU law.
- Serics Foundation (<https://serics.eu>). UNIBO research members involved in analysing the evolving EU legal framework on cyberspace.

### ***National projects***

- PRIN 2017 CBRN in Italy (<http://www.cbrn-italy.it/en/about-cbrn-italy>) - PI Andrea de Guttry - Responsible UNIBO Research Unit: Federico Casolari. UNIBO research members were involved in monitoring the implementation of the EU CBRN legislation in the Italian legal system
- PRIN 2022 "Health emergencies and Legal Preparedness - HELP: Global, Regional and National Approaches" - PI Emanuele Sommario - Responsible UNIBO Research Unit: Giacomo Di Federico. UNIBO research members are involved in the analysis of related EU law framework and possible developments.

## Doctoral Position

### **Enhancing Risk Prevention in Society: Advanced Mathematical Methods and Computer Science Techniques**

## Doctoral Programme

Mathematics

### Description of the doctoral position's main topic

The PhD project will focus on developing advanced mathematical models and computer science tools for risk prevention in society, with a strong emphasis on leveraging big data techniques. This interdisciplinary project encompasses three main research themes: design of optimal response strategies, mitigating risk in epidemics, and prevention of cyber-attacks.

A first line of research encompasses the development of mathematical models and computational algorithms aimed at optimizing disaster response strategies. This includes but is not limited to, enhancing evacuation planning protocols, effectively allocating resources, and facilitating the coordination of emergency services. To achieve these objectives, stochastic optimization techniques such as consensus-based optimization (CBO) methods will be employed, leveraging their capacity to iteratively converge towards optimal solutions by aggregating information from multiple agents. Additionally, the use of machine learning approaches will play a pivotal role in capturing the complex dynamics inherent in disaster scenarios, enabling a more accurate representation of system behaviour.

The second direction of research involves the development of mathematical models to assess epidemic risk within communities, integrating principles of kinetic theory, epidemiology, and collective dynamics. This interdisciplinary approach aims to understand how disease transmission interacts with social connections, ultimately informing effective policy and control measures. By simulating various scenarios and interventions, the project will provide valuable insights into the spread of infectious diseases and the design of efficient preventive measures. Such research contributes to evidence-based policymaking, enabling proactive strategies to mitigate epidemic risk and foster community-wide consensus on public health measures, thus enhancing overall disease control efforts.

The last research field considers the fact that modern industrial environments face not only the safety and security challenges arising from the convergence of Information Technology (IT) and Operational Technology (OT), but also the fact that there is no longer a single, enterprise-wide perimeter. To address such issues, one should analyze pros and cons of adopting in the industrial landscape the Zero Trust Architecture (ZTA), a



strategy removing the assumption that connected devices within the enterprise borders should be trusted. The research will investigate the adoption of Next Generation Firewalls (NGFWs) and Digital Twins (DTs) in the edge-to-cloud continuum, also by defining and dynamically evaluating the trustworthiness of deployment environments.

The PhD project aligns with regional, national, and global efforts in disaster management, public health, and cybersecurity. It offers career opportunities in academia, government, and private sectors, focusing on enhancing societal resilience and security through interdisciplinary research.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Lorenzo Pareschi, Giacomo Dimarco, Carlo Giannelli.

### Doctoral candidate's desirable skills and competences

#### ***Scientific and technical skills***

For the first and second research directions the candidate should have some familiarity with partial differential equations and some elementary course of numerical analysis. The knowledge of programming languages such as Matlab, Python or Julia (but C/C++ or Fortran can be used as well) will help the candidate to advance especially in the first research topic.

For the third line of research, while it is not required that the candidate has previous experience within the cybersecurity research field, it is a requirement a good knowledge about basilar aspects of operating systems, networking, web applications, programming, and Linux administration.

### Description of the research group(s) in which the doctoral candidate will be integrated

The successful candidate will be hosted at the Department of Mathematics and Computer Science of the University of Ferrara and will be member of the Center for Modeling, Computing and Statistics (CMCS). The Department is a node of the Marie-Curie Doctoral Network DataHyking. In the following a brief description of the key members of the research group their main research interest and achievements. Lorenzo Pareschi is the Chair of Applied and Computational Mathematics at Heriot-Watt University, Edinburgh UK, and Professor of Numerical Analysis at the University of Ferrara. He obtained his Ph.D. in Mathematics from the University of Bologna. His primary research activities focus applied and computational mathematics, optimization, uncertainty quantification with a focus on hyperbolic and kinetic equations. He was recognized as a Nelder Fellow at Imperial College, London, UK, in 2015, a John von Neumann Professor at the Technical University of Munich, Germany, in 2019, and a Wolfson Fellow of the Royal Society in 2023. He is associate editor for several international journals, including Multiscale Modeling and Simulation and SIAM Journal on

Scientific Computing. He has authored over 200 scientific publications and 5 books. Giacomo Dimarco received the Ph.D. degree in applied mathematics from the University of Ferrara. He is currently Professor in Mathematical Physics at the University of Ferrara. He was Assistant Professor at the University of Toulouse, France, from 2009 to 2013 and Associate Professor in numerical analysis from 2013 to 2021 in Ferrara. His primary research activities focus mathematical modeling, computational mathematics, kinetic theory, control and uncertainty quantification. He is Associate Editor of Journal of Computational Physics and Annali of the University of Ferrara. He is the Director of CMCS and next Director of the Department of Mathematics and Computer Science. Carlo Giannelli received the Ph.D. degree in computer engineering from the University of Bologna. He is currently an Associate Professor in computer science at the University of Ferrara. His primary research activities focus on Industrial Internet of Things, Digital Twin management, Software Defined Networking, Blockchain technologies, and cybersecurity in Industry 4.0. He serves on Editorial Boards of COMCOM and EURASIP JWCN. Carlo Giannelli is part of the Distributed Systems research group at the University of Ferrara, carrying out scientific research in various fields, such as Big Data, Cloud/Edge/Fog Computing, IoT in Industry 4.0 and Smart City environments, IT service management and opportunistic networking.

For more detailed information about the group's research activities and achievements, additional details can be found on the following web pages:

<https://dmi.unife.it/en>

<https://www.unife.it/centri/centro/modeling-calculation-and-statistics-centre>

<https://ds.unife.it/>

<https://datahyking.eu>

Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The Department of Mathematics and Computer Science will provide all necessary equipment and computing resources necessary to conduct the research. In addition, the candidate will join the CMCS and the DTCS research teams.

CMCS is an interdepartmental research centre affiliated with the University of Ferrara, promoted by the departments of Mathematics and Computer Science, Economics and Management and Engineering. The centre involves several researchers from different Italian universities. The primary function of the CMCS is to carry out research in various disciplines, including applied mathematics, numerical analysis, scientific computing, computational fluid dynamics, machine learning and statistics. The final aim foresees the application of the scientific goals achieved to real and tangible problems, through the development and implementation of mathematical models and software. In addition, the centre is committed to organizing

educational and public events, of a national and international nature, related to cultural, scientific, and technical innovation in the areas of expertise of the centre.

The Digital Twin and Cybersecurity (DTCS) research team (part of the Distributed System research team) at the University of Ferrara, aims at investigating, analysing, and experimentally validating Zero Trust techniques and the Digital Twin paradigm to prevent, identify, and counterattack cyber-attacks and cyber threats. The research DTCS team is focused on IoT devices and industrial environments, but the same solution can be validated within Smart Cities environments. In addition, the DTCS research team designs and develops innovative solutions aiming at exploiting the Blockchain technology in industrial environments, by exploiting state-of-the-art platforms such as Hyperledger Fabric, and by extending traditional solutions to provide innovative features, e.g., to allow the resiliency of industrial environments even if (partially) compromise by an attack.

### Collaboration networks involving the research team

The applied mathematical group has established structural and ongoing scientific collaborations with prestigious international research institutions such as CNRS and INRIA, the University of Toulouse, Nice, Rennes in France, Aachen, Kaiserslautern in Germany, Oxford, Edinburgh in UK, Shanghai in China, Courant, Madison, and Washington University in USA. The computer science group has also established structural and ongoing scientific collaborations with prestigious international research institutions such as the Florida Institute for Human & Machine Cognition (IHMC) of Pensacola, FL, USA and IBM TJ Watson Research Center in New York, NY, USA.

The DataHyking network involves six partner universities (Leuven, Nice, Aachen, Kaiserlautern, Rome, Ferrara) and is a European Doctoral Network with the aim to create a data-driven simulation framework for kinetic models of interacting particle systems. DataHyking is focused on developing reliable and efficient simulation methods, designing robust consensus-based optimization, also for machine learning, and developing multifidelity methods for uncertainty quantification and data assimilation. Applications involve traffic flow, finance, and granular flow, also in collaboration with industry. The PhD candidate will be fully involved in the network events and scientific collaborations.

The DTCS research team is involved in the EU 6G Smart Networks and Services Industry Association (6G-IA) <https://6g-ia.eu/>, providing the perspective of EU industry and research institutions on the next generation of networks and services. Its main objective is to contribute to the EU's leadership role in research areas related to 5G, 5G evolution, Smart Network Service (SNS) and 6G. 6G-IA carries out a wide range of activities in strategic areas including standardization, research and development projects, technological expertise, collaboration with key sectors of industry vertical markets, for trial development and for international cooperation.

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

The candidate will join the DTCS research team to actively participate in several active funded projects carried on together with several other Italian and international universities.

#### ***European Projects***

- “DATAHYKING - Data-driven simulation, uncertainty quantification and optimization for hyperbolic and kinetic models”, HORIZON-MSCA-2021-DN-01-01 - MSCA Doctoral Networks 2021. University of Ferrara, KU Leuven, Roma La Sapienza, INRIA, University of Nice, University of Kaiserslautern, RWTH Aachen University. Lorenzo Pareschi scientific responsible for University of Ferrara.

#### ***National projects***

- “Advanced numerical methods for time dependent parametric partial differential equations with applications”, MIUR-PRIN 2022 project, Lorenzo Pareschi responsible of local unit.
- “Integrated Mathematical Approaches to Socio–Epidemiological Dynamics”. PRIN 2020, Giacomo Dimarco responsible of the Research Unit. PNRR Future HPC & BIG DATA. Participants of the unit of the University of Ferrara.
- “IntelliGent and secure Networking in IndusTriAl Environments: towards Industry 5.0 – IGNITE 5.0”, PR-FESR 2021-2027 Regione Emilia Romagna, Carlo Giannelli responsible of local unit.
- “Cyber range for industrial security - CRI4.0”, PR-FESR 2021-2027 Regione Emilia Romagna, Carlo Giannelli responsible of local unit.
- “Cybersecurity for Smart Industry - C4SI”, PR-FESR 2021-2027 Regione Emilia Romagna, Carlo Giannelli responsible of local unit.
- “DATRUST - Connecting the physical and DigitAl worlds through TRUSTworthy dataflows”, PRIN 2022 PNRR, Carlo Giannelli responsible of local unit.

Design of off-shore structure through Physically Based Meshless Scheme augmented via Data-Driven Models

## Doctoral Position

### **Design of off-shore structure through Physically Based Meshless Scheme augmented via Data-Driven Models**

## Doctoral Programme

Civil Engineering and Architecture

### Description of the doctoral position's main topic

The position aims to seamlessly integrate a physically based meshless scheme, specifically Smoothed Particle Hydrodynamics (SPH), with data-driven models based on artificial intelligence to revolutionize the way we harness energy from our oceans. The candidate will have the opportunity to work on cutting-edge research at the intersection of engineering, computational science, and renewable energy, utilizing the DualSPHysics open-source software (<https://dual.sphysics.org/>).

Offshore facilities play a crucial role in the exploration and utilization of ocean energy resources. However, traditional design approaches often face challenges in accurately predicting the behavior of offshore structures under varying environmental conditions. This position seeks to overcome these challenges by developing a novel methodology that combines physics-based meshless schemes, particularly Smoothed Particle Hydrodynamics (SPH), with data-driven models based on artificial intelligence techniques such as machine learning and neural networks.

Smoothed Particle Hydrodynamics (SPH) is a meshless Lagrangian method that has gained popularity in fluid dynamics simulations due to its ability to handle free surface flows, complex geometries, and large deformations with ease. The DualSPHysics open-source software is a widely used platform for conducting CFD simulations, offering capabilities for simulating fluid-structure interactions, wave propagation, and particle-based modeling of coastal and offshore engineering applications.

The position will contribute to groundbreaking research in offshore renewable energy design, pushing the boundaries of current knowledge and will offer the opportunity to involve candidates in a truly global research environment with the opportunity for a secondment period at the University of Manchester, UK, working alongside leading experts in the field.

## Sub-themes of the doctoral position's main topic (if any)

None

## Potential Supervisors

Renato Vacondio, Paolo Mignosa

## Doctoral candidate's desirable skills and competences

### ***Scientific and technical skills***

A robust foundation in numerical modeling and simulation is essential. While prior experience in Computational Fluid Dynamics (CFD) is advantageous, it is not obligatory.

Conduct literature review and background research on offshore facilities design, numerical simulations, Smoothed Particle Hydrodynamics (SPH), and artificial intelligence.

Develop and implement numerical algorithms for SPH simulations of offshore structures using the dualSPHysics software. Integrate data-driven models with the SPH scheme to enhance predictive capabilities for offshore facility design.

### ***Other skills***

Collaborate with interdisciplinary teams to validate and optimize the developed approach through experimental and field data.

Publish research findings in peer-reviewed journals and present at international conferences.

## Description of the research group(s) in which the doctoral candidate will be integrated

The research group, active at the Department of Engineering and Architecture (DIA) of the University of Parma, focuses on water-related issues in the fields of Civil Engineering and Environmental Engineering and Territorial Planning. The group's activities span both experimental works, leveraging the Hydraulics laboratory, and mathematical modeling. In the field of Hydraulic Protection against surface water, research topics include the quantification and management of hydraulic risk in the territory, employing mathematical models for flood formation and propagation, flood dynamics, design and verification of flood retention basins, and the development of physical models. Regarding aspects of Hydraulic Protection of groundwater, studies are conducted on quantitative and qualitative issues related to aquifers. Specifically, mathematical modeling of water flow in regional aquifers is utilized to identify more efficient strategies in water resource management. Theoretical-numerical studies are ongoing for simulating the transport of pollutants in aquifers to fully describe the evolution of pollution episodes (direct problem) and to identify hydraulic parameters (inverse problem) that influence aquifer behaviour.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

UNIPR has centralized and unit-based support facilities, research infrastructures, and conference areas. Staff have access to computers, offices, reading and meeting rooms, software for various discipline/specific computing needs, face-to-face videoconferencing equipment, and a rich library collection.

UNIPR has a proven expertise in the field of big data, artificial intelligence and advanced computation. UNIPR is member of the regional association "Big data" which includes research centres and infrastructures leaders in High Performance Computing and Big Data management. Furthermore, in 2022 it entered in the Hub of National Centre for HPC, Big Data and Quantum Computing.

UNIPR has its own High Performance Computing Cluster (recently expanded with 1 Tb RAM and 164 cores) used by researchers of different disciplines: physicists, engineers, physicians, geneticists, economists, chemists and even art historians. UNIPR has access to CINECA pre-exascale machine LEONARDO.

Located at the Science and Technology Campus is the Technology Transfer and Material Testing pavilion, which plays a valuable role in protecting and commercializing intellectual property developed by UNIPR staff.

Within the campus is also located a leading Technopole for industrial research, that includes cutting-edge research centres and laboratories operating in different industrial sectors.

## Collaboration networks involving the research team

The position of Chair of SPHERIC (SPH Research and Engineering International Community) offers the primary supervisor a unique opportunity to pinpoint ideal collaborations with both academia and industry for the candidate. Additionally, the participation of Prof. Benedict Rogers as a co-supervisor will further facilitate the engagement of the PhD student within an extensive international research network. Prof. Rogers, who leads the SPH research group at the University of Manchester, currently heads one of the largest researches centers worldwide focusing on this subject matter.

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

### ***National projects***

- ECOSISTER Avviso MUR 3277/2021 "Ecosystem for Sustainable Transition in Emilia-Romagna" Funded by Next Generation EU. EU fundings (2022 - 2025) total funding 110 M€. Renato Vacondio is Coordinator of Work Package 3 - Spoke 6, Prof. Paolo Mignosa, Dr. Valeria Todaro and Dr. Susanna Dazzi are members of the research group.

- ARES - Artificial intelligence for flood RESilience PhD Student scholarship funded by Regione Emilia Romagna (2021 - 2024) fully funded 3-years PhD student. PI: Prof. Renato Vacondio
- MINIMUM - Massively parallel and multi-scale Numerical sIMULations for survivability of Marine structures, 2 years (2022 - 2023), 24'000 €, Supervision of a PhD Student. DM 737 25.06.2021 University of Parma. PI: Prof. Renato Vacondio
- Andritz-SPH: Principal Investigator of the Research Project: "Development of an algorithm to control particles distribution in Smoothed Particle Hydrodynamics simulations". 3 years (2018 – 2021), 102.000 €. Supervision of a PhD Student. PI: Prof. Renato Vacondio
- PARFLOOD: Principal Investigator of the Research Project: "FLOOD risk management based on PARallel numerical simulations", ID RBSI14R1GP, funded by the SIR (Scientific Independence of young Researchers) programme by Italian Ministry of University and Research (MIUR), year 2014. 3 years, 383.023 €, Supervision of 1 PhD Student (XXXII Cycle) and 1 Post Doc (1 year). PI: Prof. Renato Vacondio
- RESILIENCE: Co-PI of the research project "REsearches on Scenarios of Inundation of Lowlands Induced by EmbaNkment Collapses in Emilia-Romagna" funded by the Italian Civil Protection Agency. 5 years (2015 – 2024) 340'000 €. PIs: Prof. Renato Vacondio and Prof. Paolo Mignosa. Dr. Susanna Dazzi, Dr. Alessia Ferrari and Prof. Francesca Aureli members of the research team.
- AFFORD: Principal Investigator for the project AFFORD - Automatically adaptive SPH scheme For FIOod Risk reduction. Funded by Università di Parma (5'000 €), years 2017 – 2018. PI: Prof. Renato Vacondio
- PGRA: Prof. Renato Vacondio Principal investigator and coordinator of the Scientific Research for the assessment of the flood hazard in the Po river basin. Funded by the Po Basin River Authority (AdBpo, <https://adbpo.gov.it/>), In collaboration with Politecnico di Milano, Politecnico di Torino, Università di Bologna, Università di Padova, Università di Pavia, Università di Brescia, 1'100'0000 €. years 2019 – 2021.

## Other projects

- Variable Resolution for DualSPHysics. Reserach contract funded by New Jersey Institute of Technology (USA) (2023 - 2024), 70'000 €. PI: Prof. Renato Vacondio



## Doctoral Position

### **Data mining for space borne astrophysical and cosmological observations**

## Doctoral Programme

Physics

### Description of the doctoral position's main topic

Space based observations are revolutionizing our understanding of the Universe by flooding us with high quality data in spectral bands that are poorly accessible from Earth. Furthermore, space – and, in particular, the Sun-Earth Lagrangian point L2 – is a very stable and convenient spot for long term deep space observations, exploited by world leading space agencies. This project focuses on data analysis from large, rich, complex astrophysical datasets gathered from space borne telescopes, either already acquired or forthcoming. The successful candidate will make use of advanced data mining techniques, including machine learning and HPC, taking advantage of some of the world's best supercomputing centres. The scientific context of this project is oriented along three main axes:

1. Big data from the early Universe, focusing on the exploitation of cosmic microwave background (CMB) datasets. It has been extensively observed by the ESA Planck satellite, to constrain cosmological models. This group has been a leading node of the Planck analysis, and the mining of legacy Planck data is an opportunity for the present project. The polarization of the CMB is a probe of cosmological inflation by targeting its primordial gravitational wave (GW) background. This is the forefront of current research and will be the target of several observational efforts, including the JAXA LiteBIRD. The Ferrara group participates in the development of LiteBIRD in data management and simulations, several opportunities in terms of data exploitation and international cooperation in academic and non-academic institutions (including JAXA in Tokyo and ASI in Rome). The CMB is the oldest electromagnetic signal we receive from the Universe and encodes a wealth of cosmological information. The anisotropies in the CMB trace the primordial perturbations that seed the formation of structure in the Universe and have been extensively observed by the ESA Planck satellite, to constrain the cosmological model. The data legacy of Planck provides strong opportunities for research projects focused on data mining. LiteBIRD is a lively collaboration whose science requires innovative data exploitation techniques, especially for keeping systematic effects under control. This

provides opportunities to collaborate with European and Japanese industries. Furthermore, LiteBIRD is synergic to several ground based observational efforts, including the US Simons Observatory currently operating in Chile and the (DOE and NSF) CMB-S4, a network of telescopes at South Pole and Chile to observe the small-scale CMB, in which the Ferrara group is also participating.

2. Galaxy surveys and in particular the ESA Euclid satellite, which has been launched in 2023 and has recently started observations. The Ferrara group has an extensive participation in Euclid data exploitation, in particular for cross-correlations with CMB data and theoretical modeling. This research avenue also has several potential hosts, both academic and non-academic, including ESA. The focus here will be in developing innovative data mining techniques to exploit the cross correlations with CMB data and constraining theoretical models for the early Universe. Euclid is expected to release proprietary data to collaboration members within the time frame of this project. Opportunities for collaboration include ESA, ASI and several institutions in Europe (in particular, in France).

3. Multimessenger observations of neutron star mergers, focusing on analysis of electromagnetic (EM) signals. The joint detection of GW and EM signals from such a merger has ushered a new era of opportunities to answer fundamental questions. In the near future, the advent of new and improved GW and EM facilities - including space telescopes operating in the optical/infrared bands (e.g., James Webb, Nancy Grace Roman) and at X-ray/gamma-ray frequencies - will dramatically increase the number of multi-messenger events detected. The Ferrara group participates in several international collaborations leading the field of multi-messenger GW astronomy (e.g., ENGRAVE, ZTF) and plays a leading role in the exploitation of multi-messenger data through the use of sophisticated codes. On Aug 17, 2017, the joint detection of gravitational waves (GWs) and EM signals from the merger of two NSs marked year zero of the multi-messenger GW era and provided a window to answer fundamental questions concerning the origin of heavy elements we find on Earth, the rate of expansion of our Universe and the equation of state of nuclear matter.

All the above research topics have high potential for post-PhD opportunities, in academia, industry and interconnected organizations, such as space agencies.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Mario Ballardini, Mattia Bulla, Martina Gerbino, Alessandro Gruppuso, Massimiliano Lattanzi, Paolo Natoli, Luca Pagano

### Doctoral candidate's desirable skills and competences

#### ***Scientific and technical skills***

Expertise in high-level programming languages is recommended. Expertise in HPC and/or machine learning/data mining techniques and/or code parallelization as well as in analysis of astrophysical and cosmological data is helpful, as well as expertise with developer platforms such as GitHub. Preliminary knowledge of astrophysics and cosmology can be useful but is by no means mandatory.

## Description of the research group(s) in which the doctoral candidate will be integrated

This Research Group includes members from the University of Ferrara, the Ferrara INFN unit, and INAF Bologna. The group is active on complementary aspects from projects with a mostly-phenomenological flavor to the development and validation of data analysis pipelines. One strong asset is the exploitation of CMB data. Other avenues for this project are tied to galaxy surveys and multi-messenger astrophysics. The main research activities can be linked to the following areas: – Theoretical Cosmology. The group mission is to investigate aspects of fundamental physics with cosmological probes. This is achieved in light of current and future observations of international experiments, either space-borne (Planck, LiteBIRD, Euclid), or sub-orbital (LSPE, Simons Observatory, CMB-S4). The main research activities of the group include the study of the early Universe (inflation, violation of fundamental symmetries in Nature, cosmic anomalies), the investigation of the nature of dark matter and dark energy, the study of fundamental particles and their properties (neutrino cosmology, and particle cosmology at large). – Data analysis and pipeline development. The group has decades-long experience in this field. Members of the group have contributed to the success of several CMB missions, the Planck mission among all, playing important roles within the corresponding collaborations. Currently, the group is involved in several collaborations, including LiteBIRD, LSPE, Simons Observatory, CMB-S4, and Euclid. The group activities are focused on: development of end-to-end simulations, with emphasis on the modeling of instrumental systematics, in order to propagate their uncertainties to science products; development and validation of data analysis pipelines, including building algorithms for the statistical analysis of the data and for their reduction to final analysis products (for example, maps to power spectra). – Multi-messenger. The group mission is to study neutron star mergers through gravity and light. The group has developed sophisticated numerical codes using radiative transfer to model the EM signals of neutron star mergers at optical/infrared wavelengths. These models have been used widely in the literature and are currently employed by international collaborations (e.g., ENGRAVE, ZTF) the group belongs to and that are leading the multi-messenger field. The group has played a significant role in the development of an open-source nuclear-physics multi-messenger Bayesian framework (NMMA) that enables a truly multi-messenger analysis of GW and EM signals from neutron star mergers. Members of the group all have in common a strong degree of multidisciplinary. The group gives great importance to the ability to switch between theoretical, observational, and phenomenological activities. Further information: For more detailed information about the group's research activities and achievements, additional details can be found on the Cosmology group web pages:

<http://www.fe.infn.it/cosmologia>

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The group has close connections with the National Institute for Nuclear Physics (INFN, which maintains a division inside the Department), the National Institute for Astrophysics (INAF) and the HPC consortium CINECA. Through CINECA, the group has access to High Performance Computing facilities. In particular, access is granted to the newly deployed pre-exascale system Leonardo, which features two partitions allowing it to run on both CPUs and GPUs. A local small-scale computing cluster equipped with both CPUs and GPUs is also available for development, testing and small-scale production. This local system will soon be integrated with new super-chip NVIDIA Grace Hopper (high number of CPU cores) and new-generation GPU (i.e. NVIDIA Hopper), both accessing the same memory (this peculiarity is not a common feature in currently available computing systems). To members of scientific collaborations, access is also granted to the US supercomputing facility NERSC, with allocation limited to collaboration activities. Standard equipment (laptop, monitor, keyboard, mouse, storage systems) is provided as needed. PhD students are provided a personal desk in a shared room with students from adjacent research areas. A common area for breaks and informal chats is also available.

## Collaboration networks involving the research team

The successful candidate will have access to a rich network of international collaborators. The group is deeply involved in several flagship scientific collaborations such as the satellite missions LiteBIRD (launch expected in early 2030s) and Euclid (currently operating), the ground-based experiments Simons Observatory (currently operating) and CMB-S4 (operations to start in 2030s), and collaborations leading multi-messenger astronomy at national (GRAWITA) and international (ENGRAVE, ZTF) level, including in coordination and governance roles. Membership can be granted based on the relevance of the PhD project for the specific collaboration. Continuous collaborations with members of national and international institutions (academic and research institutes) are also ongoing. A few examples include: IFIC Valencia, Cardiff University, Orsay IAS, Kavli IPMU, KEK, Okayama (Japan), Stockholm University, University of Potsdam, Joint Space-Science Institute, University of Minnesota, CNRS IAS and IAP (Paris). Visiting international institutions during the PhD program as well as participating in conferences and workshops is encouraged by the group. A rich program of seminars and visitors by national and international collaborators is also organized every year.

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

### ***European Projects***

- CMB-Inflate (MSCA-RISE-2020 - Research and Innovation Staff Exchange; local coordinator P. Natoli): Funds staff exchange (travels) to selected academic and non academic centers in Japan, US, Canada and Vietnam.
- RELiCS (HORIZON ERC-Starting 2023; PI M. Gerbino): project to lead new CMB experiments towards discoveries in particle physics.
- AHEAD2020 (EU Horizon 2020; Integrated Activities for High Energy Astrophysics): The Astrophysics group (M. Bulla, C. Guidorzi and local coordinator P. Rosati) is part of AHEAD2020 (EU Horizon 2020; Integrated Activities for High Energy Astrophysics), a Research Infrastructure program to integrate and open infrastructures for high energy Astrophysics.

### ***National projects***

- SHIFT (PRIN2022; PI M- Gerbino): national network to build empirically the statistical distribution of shifts in the bestfit values of cosmological parameters obtained from different CMB experiments.
- BROWSEPOL (PRIN2022; co-PIs P. Natoli and A. Gruppuso): national network to investigate new physics from current and future CMB polarized data.
- ICSC: The group participates in the HPC center ICSC, The High-Performance Computing, Big Data e Quantum Computing Research Centre, established by the National Recovery and Resilience Plan (PNRR). P. Natoli is a coordinator for Spoke2 / Work Package 3 (astroparticle and gravitational waves) activities, with T. Brinckmann and L. Pagano as participants. P. Campeti, M. Gerbino and M. Lattanzi are members of the Spoke 3 (astrophysics and cosmos observations). The center targets technological developments for scientific computing and provides access to top-notch computing systems (HPC CPU and GPU, cloud).
- LiteBIRD: Local coordinator P. Natoli: ASI and INFN fundings for project development, personnel and travels.
- Euclid: Local coordinator P Natoli (ASI) and M. Lattanzi (INFN), fundings for project development.
- InDark: National and local coordinator M. Lattanzi. INFN project to support Theoretical Cosmology.

## Doctoral Position

### **Deep learning for renal pathology prognosis prediction**

## Doctoral Programme

Information and Communication Technologies

### Description of the doctoral position's main topic

The project aims at designing, implementing and testing artificial intelligence prognostic tools for different kinds of medical conditions (such as the IgA Nephropathy, to give an example). Being able to predict accurately the prognosis of a disease is essential to evaluate the best therapeutic approach. An accurate prognosis definition is therefore essential to correctly modulate the therapeutic strategies.

The application of artificial intelligence algorithms allows for the interpretation of medical images with accuracy comparable to that of humans, but with response times and costs that are only a fraction of the human counterpart. In previous scientific collaborations, our group has developed a deep learning algorithm that is able to extract with significant accuracy the histopathological features of the renal immunofluorescence image and we plan to support the PhD candidate in further developing similar techniques for different organs. Thanks to the collaboration with multiple medical centres in EU we have the availability of significant samples of subjects affected by different pathologies together with histological slides and clinical follow-up data. Through Machine Learning techniques, prognostic information will be extracted from these multidimensional data.

Exchange of sensitive medical data is a major obstacle to the research development, because of very important privacy issues. Another PhD effort will be devoted to facilitate the transfer of knowledge, in order to build machine learning systems that can benefit from decentralized knowledge without dealing with the exchange of sensitive data between centres. We plan to study and apply federated learning techniques in the context of continuous learning with particular attention to the type of knowledge transmitted between the learning nodes so that the privacy of the data is preserved but the information learned by the systems is maximized.

Through the project, the candidate will acquire the typical skills of an AI architect with particular emphasis on the development of privacy-aware and resilient systems. This professional figure is emerging as a key figure to enable AI transformation processes in compliance with the guidelines towards responsible and trustworthy AI dictated at European level.

By leveraging federated learning, multiple institutions can collaborate while ensuring data privacy, contributing to advancements in disease diagnosis, treatment planning, and personalized medicine. This role involves developing innovative algorithms, working with large-scale medical datasets, and collaborating with interdisciplinary teams to translate research into real-world impact, making a meaningful difference in patient outcomes and healthcare delivery.

UNIMORE is at the center of the Biomedical Valley (Mirandola District), the largest biomedical district in Europe, and the third one in the world after Minneapolis and Los Angeles. This obviously opens multiple career opportunities for PhDs.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Costantino Grana, Simone Calderara, Federico Bolelli, Luigi Rovati

### Doctoral candidate's desirable skills and competences

#### ***Scientific and technical skills***

The project aims to analyze the design of new privacy preserving and low environmental impact machine learning techniques with particular emphasis on applications of medical image analysis. The candidate should have basic knowledge on deep learning methods for image analysis and possibly continuous and federated learning techniques. The candidate will acquire knowledge that allows her/him to build distributed learning systems and integrate online learning and knowledge transfer methodologies. The candidate should also apply knowledge transfer methods between deep models, specifically knowledge distillation between deep neural networks.

### Description of the research group(s) in which the doctoral candidate will be integrated

The research group is composed of people from AlmageLab ([www.aimagelab.unimore.it](http://www.aimagelab.unimore.it)), which is a research lab in Artificial Intelligence with more than 20 researchers, focusing mainly on Deep Learning and Computer Vision. AlmageLab is an ELLIS network unit. AlmageLab has a large experience on dataset creation and evaluation, machine learning for Medical Imaging segmentation and classification (DeepHealth EU project), human behaviour understanding (with EU projects in automotive and collaborative robots), semantic video segmentation and annotation for Cultural Heritage and image and video captioning in natural language. It has been appointed as one of the 15 European Facebook AI research Labs (FAIR) and as Ferrari RedVision Lab for automotive research. AlmageLab also has a three-year collaboration with Panasonic Silicon Valley Lab for Deep Learning, a collaboration with NSTU Norway, and one with Aalto Univ. Finland for DL and Vision. The unit led by Prof. Grana has contributed the CPU and GPU Connected Component Labeling algorithms in

OpenCV, used by hundreds of thousands of programmers worldwide. This unit specializes in 2D and 3D medical imaging applications, for skin lesion analysis, nephrology, prostate cancer detection and for maxillofacial images segmentation.

For more detailed information about the group's research activities and achievements, additional details can be found on the following web pages: <https://aimagelab.ing.unimore.it/imagelab/people.asp>

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

UNIMORE and AlmageLab feature a distributed multi-user GPU infrastructure with 15 GPU-powered servers (with NVIDIA 2080 Ti, Quadro RTX 6000, V100 and A100 GPUs), for a total of 56 high-end GPUs and 16 development GPUs. It has a SLURM queue system, and a 400 TB RAID6 storage powered by 25GbE. Further, it has an infrastructure for virtual machine deployment with shared storage and 10GbE connectivity. The AlmageLab laboratory also has two programmable robots for research on human-robot interaction and several RGB, RGB-D, thermal and infrared cameras for dataset acquisition.

AlmageLab has a continuous partnership with CINECA, which grants UNIMORE PhDs access to the 6th largest supercomputer in the world.

## Collaboration networks involving the research team

AlmageLab is part of ELLIS, the European Laboratory for Learning and Intelligent Systems. ELLIS is a pan-European AI network of excellence which focuses on fundamental science, technical innovation and societal impact. Founded in 2018, ELLIS builds upon machine learning as the driver for modern AI and aims to secure Europe's sovereignty in this competitive field by creating a multi-centric AI research laboratory. ELLIS wants to ensure that the highest level of AI research is performed in the open societies of Europe and follows a three-pillar strategy to achieve that.

The Modena (UNIMORE) unit is directed by Prof. Rita Cucchiara (ELLIS Fellow), and Simone Calderara, Costantino Grana, Roberto Vezzani, Lorenzo Baraldi, Marcella Cornia, Enver Sangineto are ELLIS members.

AlmageLab has many active collaborations with national and international research groups, and in particular for this program, the main link will be with Radboud University (Nijmegen, The Netherlands), which actively collaborates with AlmageLab on Medical Imaging tasks, e.g. the MICCAI ToothFairy Challenge which is now at the second edition. Another important collaboration is with Universitat Politècnica de València, which participated with UNIMORE in the DeepHealth project and together developed the European Distributed Deep Learning Library Framework.



International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

***European Projects***

DECIDER – “Clinical Decision via Integrating Multiple Data Levels to Overcome Chemotherapy Resistance in High-Grade Serous Ovarian Cancer” – Grant agreement ID: 965193; Horizon 2020; 01/02/2021 – 31/07/2026; Elisa Ficarra; development of deep learning algorithms for whole slide image analysis integrated with genomic information.

Horizon 2020 - ELISE - "European Learning and Intelligent Systems Excellence" – Grant agreement ID: 951847. 01/09/2020 - 31/08/2023; Costantino Grana; diffusion of machine learning result and exchange of researches and students.

Horizon 2020 - DeepHealth – “Deep-Learning and HPC to Boost Biomedical Applications for Health” - Grant agreement ID: 825111. 01/01/2019 - 30/06/2022; Costantino Grana; development of the EDDL and of ECVL libraries for medical image analysis.

***National projects***

FIT4MEDROB - “Fit for Medical Robotics: A new generation of biorobotic and digital technologies for a sustainable welfare”; PNRR; Rita Cucchiara; development of machine learning techniques for medical robotics and human interaction.

## Doctoral Position

### **Big Data Analysis for Industrial Diagnostic**

## Doctoral Programme

Industrial Innovation Engineering

## Description of the doctoral position's main topic

The advent of Industry 4.0 and the progression towards Industry 5.0 have emphasized the essential role of big data in transforming industrial diagnostics. With the expansion of IoT and IIoT devices, there's a growing ability to collect extensive amounts of data across the supply chain, offering unique opportunities for predictive maintenance, operational efficiency, and informed decision-making. IoT and IIoT technologies are foundational for data collection in industrial environments, providing real-time insights and control. Their application across various sectors enables the gathering of crucial performance and operational metrics, vital for diagnostics and predictive analytics.

Digital twins mark a significant advancement in how we model, visualize, and analyse industrial processes. By creating digital replicas of physical assets, digital twins allow for a deeper understanding of system behaviours, identifying performance limits and potential failures, thereby enhancing industrial diagnostic processes and enabling system integration. Using machine learning and artificial intelligence algorithms to analyze big data sets reveals patterns and trends beyond human analysis. These technologies are key in predicting equipment failures, optimizing maintenance schedules, and strengthening supply chain resilience.

However, the widespread adoption of these technologies in industrial diagnostics faces several open challenges:

- Concerns around data privacy and security, heightened by the sensitivity of industrial data and the introduction of new technologies like federated learning.
- Challenges in achieving interoperability among various IoT/IIoT devices and legacy systems, complicating data integration efforts.
- The complexity involved in processing and analysing large volumes of real-time data for actionable insights.
- The need to ensure the reliability and accuracy of ML/AI models in dynamic and unpredictable industrial settings.

The Ph.D. student will focus on the integration of IoT/IIoT, Digital Twins, ML/AI and Federated Learning technologies, which holds the promise to revolutionize industrial diagnostics, steering the sector toward

predictive and adaptive maintenance strategies. These strategies are pivotal in significantly reducing downtime and operational costs. Addressing the mentioned challenges is essential for unlocking the full potential of big data in industrial diagnostics, thereby facilitating the development of more intelligent, efficient, and sustainable industrial ecosystems.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Marco Mamei, Marco Picone, Marcello Pietri

### Doctoral candidate's desirable skills and competences

#### ***Scientific and technical skills***

For a project focusing on Big Data for Industrial Diagnostics, the candidate must possess a strong foundation in data science and analytics, including a bit of expertise in statistical analysis, machine learning algorithms, and data preprocessing techniques. Proficiency in programming languages such as Python, Java or R is essential. Familiarity with big data platforms like Hadoop or Spark and

Knowledge of industrial systems and IoT technologies, understanding the principles of industrial diagnostics and maintenance strategies, will be highly beneficial. Experience with sensor data analysis and real-time data processing can also be advantageous but is not mandatory. Additionally, skills in data visualization and the ability to interpret complex datasets to derive actionable insights are necessary. While not obligatory, familiarity with cloud computing services and knowledge of cybersecurity principles related to industrial data can be useful.

The candidate should demonstrate the ability to work collaboratively in multidisciplinary teams, with strong problem-solving skills and creativity in approaching complex challenges.

### Description of the research group(s) in which the doctoral candidate will be integrated

The research group, where the doctoral candidate will be integrated, operates at the cutting edge of Artificial Intelligence, distributed systems, multi-agent and self-organizing systems, pervasive computing, machine learning, and Internet of Things (IoT) / Industrial Internet of Things (IIoT). The research work is driven by a passion for researching and applying these advanced technologies to real-world scenarios such as smart environments, industries, transportation and mobility, and networking. Our research in Digital Twins and IoT reflect a forward-thinking approach in software engineering, where we develop virtual replicas of cyber physical systems intertwined with interconnected sensors for real-time data-driven simulations. This initiative is pivotal for optimizing system performance, anticipating behaviours, and enabling preemptive maintenance strategies. In Distributed Systems, our focus lies on the utilization of microservices and

Kubernetes orchestration to break down traditional monolithic architectures, thereby enhancing system scalability and agility. This research underscores the commitment to propelling software engineering into a new era marked by increased flexibility and operational efficiency. The group's work on Pervasive Intelligence leverages the integration of data analysis, machine learning, and Artificial Intelligence within IoT frameworks. The research aims to harness vast datasets for extracting actionable insights, enabling IoT systems to intelligently evolve and adapt, thereby crafting smarter and more efficient interconnected environments. Investigations into Federated Learning stand at the frontier of machine learning and decentralized computing. The group is dedicated to creating algorithms and protocols that facilitate collaborative learning across multiple devices without compromising data privacy. The group has achieved numerous publications in esteemed journals such as ACM and IEEE Transactions, addressing topics like the integration of agents and digital twins in cyber-physical systems, the design patterns for adaptive and autonomous digital twins in Industry 4.0 digital factories, and the role of causality learning in smart factories facilitated by hierarchical digital twins. Currently, the research group is actively engaged in two prominent European projects focused on advancing ecomobility for a sustainable society, "Ecomobility for a Sustainable Society with Intelligent Mobility Solutions" and "S4C Support System for Sustainable Smart City,". Both projects underscore the commitment to contributing valuable research and technological advancements in the realm of sustainable ecomobility and smart city initiatives. For more detailed information about the research activities, existing skills, and notable results, please visit the group's website at the link: <https://dipi.unimore.it>

### Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The Department of Sciences and Methods for Engineering (DISMI) at Unimore is equipped with state-of-the-art facilities and laboratories, designed to support cutting-edge research in big data and industrial diagnostics. Doctoral candidates will have access to comprehensive computing resources, including distributed high-performance computing systems, data analysis software, and simulation tools, vital for processing and analysing large datasets. The department's laboratories are outfitted with advanced equipment for experimental research and development in digital automation, Internet of Things (IoT), and smart systems design, offering an ideal environment for doctoral candidates to conduct their research. These facilities are complemented by collaborative spaces that encourage innovation and knowledge sharing among students, researchers, and faculty.

In addition to these resources, the doctoral candidate will benefit from the department's strong ties with industrial partners and private research centres, including prominent collaborations with companies like TIM. These partnerships provide unparalleled opportunities to engage with real-world data and cutting-edge technologies, ensuring that research outcomes are grounded in practical applications and ready to address contemporary challenges in big data and industrial diagnostics. These collaborative efforts not only enhance

the research experience but also open avenues for implementing solutions in industrial settings, driving innovation and technological advancement in the field.

## Collaboration networks involving the research team

The collaboration network connected to the research team spans a broad spectrum of computer science, with a strong emphasis on distributed systems, pervasive computing, and multi-agent systems. This expansive network is composed of renowned academics and researchers from institutions around the globe, showcasing a rich, interdisciplinary research environment that offers substantial advantages for a Futuredata4EU doctoral candidate, especially those focused on big data and industrial diagnostics.

Among the key collaborators, Mirko Viroli from the University of Bologna stands out for his contributions to adaptive systems and pervasive computing, areas critical to managing and interpreting large datasets in dynamic environments. Andrea Omicini, also from the University of Bologna, has made significant strides in multi-agent systems, a field integral to the automation and optimization of data processing in industrial settings. Giovanna Di Marzo Serugendo's work at the University of Geneva on self-organizing systems provides valuable insights into creating resilient and autonomous computing frameworks necessary for handling complex diagnostic tasks. Jacob Beal from Raytheon BBN Technologies enhances the network with his expertise in spatial computing and self-organization, essential for real-world applications in data-driven decision-making and predictive maintenance. Emma Hart from Edinburgh Napier University contributes with her focus on self-adaptive and self-organizing computing systems, crucial for developing robust diagnostic tools in the industrial domain.

This network, with its global reach and multifaceted expertise, offers a doctoral candidate an exceptional opportunity to delve into a wide array of research themes, methodologies, and practical applications. By tapping into this network, the candidate gains access to cutting-edge research and collaborative opportunities that can significantly elevate the quality and impact of their doctoral work in big data and industrial diagnostics.

For a comprehensive view of this collaboration network, including publications and co-authors, visit the dblp computer science bibliography website at <https://dblp.org/pid/54/3140.html> or <https://dblp.org/pid/90/6532.html>. These platforms detail the network's extensive research activities, providing a valuable resource for identifying potential collaborations and exploring the full scope of topics relevant to the candidate's research interests.

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

The research team is involved in various projects relevant to Big Data for Industrial Diagnostics, focusing on artificial intelligence, distributed systems, and IoT. These include "Ecomobility" for intelligent mobility solutions, "S4C" for smart city sustainability, "Fluidware" introducing a new paradigm for IoT, "Coorsa" focusing on intelligent robots, "Claudette" empowering consumers with AI, and "ConneCare" for chronic disease care. These projects, funded by EU, national entities, and industrial partners like TIM, showcase an interdisciplinary approach and collaboration with leading technological innovators.

### ***European Projects***

Ecomobility - For A Sustainable Society With Intelligent Mobility Solutions - Duration: 2023 – 2026 – Funded by EU - Project Coordinator TTTECH AUTO GERMANY GMBH – Roles on cybersecurity and functional safety aspects on the sensor data fusion platform and, more generally, in the SC3-demonstrator 3 implementation.

### ***National projects***

- S4C - Support System for Sustainable Smart City - Duration: 2024 – 2025 - funded by PR FESR 2021-2027 within the smart specialization strategy (S3) and by the Development and Cohesion Fund, focusing on big data and artificial intelligence themes. It is co-financed by the EU and the Emilia-Romagna region.
- Fluidware - A novel paradigm for Large-Scale IoT Systems - Duration: 2021 – 2023 - PRIN Project FluidWare funded by Italian Government (MIUR) N. 2017KRC7KT – Roles of project coordinator, unit coordinator, WP3 leader.
- Coorsa - Intelligent Robots for the Factory of the Future - Duration: 2019 – 2021 - funded by POR FESR 2014-2020 Emilia Romagna and FSC - Roles of project coordinator.
- Claudette - Machine Learning Powered Analysis of Consumer Contracts and Privacy Policies - Duration: 2017 – 2020 - An interdisciplinary international research project attempting to empower consumers and civil society through artificial intelligence.

## Doctoral Position

**Spin Systems for Quantum Technologies: advanced computing techniques, new concepts and realistic material simulations**

## Doctoral Programme

Physics

### Description of the doctoral position's main topic

Quantum computation (QC) is among the most rapidly growing technological fields, with the potential to greatly outperform existing computers on specific tasks. Spins represent prototypical quantum systems, and are the simplest objects where quantum mechanics can be framed and numerically simulated. In the context of quantum technologies, spins in solid-state systems are natural candidate elementary units (qubits) because of their relative decoupling from the environment and of their integration in a solid-state matrix, which eliminates the need to trap them optically or electromagnetically. Besides single spins, collective degrees of freedom resulting from coupled spins in nanostructures can be used to encode qubits or multi-level units (qudits). In particular, crystals of magnetic molecules are an excellent example, where the structure is chemically engineered in a bottom-up approach at the level of synthesis and whose properties can be changed to fit specific purposes. An alternative, or complementary, top-down approach is to assemble individual atomic or molecular spins on a surface, and control them by tips or external fields.

The candidate will exploit advanced computing techniques targeting many different aspects of such nanostructures which are relevant to their exploitation as elementary units of digital QC. These may include:

- The characterization of the Hamiltonian (e.g., ab-initio computational techniques like state-of-the-art density-functional-theory, DFT).
- The characterization of environment-induced decoherence due to phonons and/or nuclear spins (e.g., ab-initio DFT techniques; DFT-based machine learning force fields for spin-phonon couplings; large-scale simulations for systems of differential equations describing the open-system dynamics).
- The design of quantum control schemes –typically based on pulse sequences or quantum-circuit setups- driving the spins to perform specific tasks in quantum technologies, like quantum simulations or sensing (e.g., optimization of pulse sequences by conventional or machine-learning techniques, large-scale numerical simulations of the driven open-system dynamics).

The research will be carried out in the framework of many established connections with international groups. These include theoretical physicists (ab-initio calculations and quantum algorithms), chemists (synthesis of new molecules) and experimental physicists (characterization of the modeled systems and actual implementation of quantum algorithms). See below for more details.

At the end of the project the candidate will have acquired a solid background in digital quantum technologies and in large-scale computational techniques. Quantum technologies are a rapidly developing field, thus career opportunities will exist both within the academic and industrial sectors. The demand for specialists is quickly growing: almost all universities in the world have started or will soon start research and teaching activities on these topics, and many new corporate actors in the field are constantly emerging, ranging from small start-ups to large corporations. In addition, the significant competences in mathematical modeling and large-scale computations are a precious transversal skill which is highly-valued in a very broad range of companies.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Paolo Santini, Alessandro Chiesa, Elena Garlatti

### Doctoral candidate's desirable skills and competences

#### **Scientific and technical skills**

Very good knowledge of quantum mechanics, good programming skills, and a good knowledge of physics of matter

### Description of the research group(s) in which the doctoral candidate will be integrated

The Spin-based Quantum Science group of the University of Parma has a consolidated activity on developing theoretical models for the quantum behaviour of spin systems at the atomic, molecular and supra-molecular level, and on their potential applications in quantum technologies, particularly quantum computation and simulation. Most of this research is carried out through the identification of suitable model hamiltonians for physical systems encoding qubits, the numerical simulation of the associated quantum behavior, and the design and optimization of control schemes inducing the desired dynamics, both in closed- and open-system setups. Hamiltonians and system-environment interactions for potential candidate qubits/qudits are obtained through information from ab-initio calculations, and from the interpretation of targeted experiments. Calculations are typically large-scale for the systems of interest. In addition, the group has a proprietary NMR laboratory where some of the control schemes mentioned above can be experimentally implemented and tested. The group has 17 members, including 4 permanent staff, and a large number of



international collaborations. The group has obtained funding from several international and national competitive projects in the last years. For more detailed information about the group's research activities and achievements, additional details can be found on the following web pages: <https://www.spinquantumscience.unipr.it/>.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

Computational facilities: dedicated workstations, high-performance-computing cluster of the University of Parma <https://www.hpc.unipr.it/dokuwiki/doku.php?id=calcoloscientifico:userguide>, high-performance computing facility at Cineca <https://www.cineca.it/en/hpc>, Jülich supercomputing center <https://www.fz-juelich.de/en/ias/jsc>. Experimental facilities: proprietary NMR laboratory <https://www.spinquantumscience.unipr.it/about-us/nmr-quantum-lab/328/>.

## Collaboration networks involving the research team

The research team has a large number of collaborations with highly recognized international groups. These include theoretical physicists (ab-initio calculations and quantum algorithms), chemists (synthesis of new magnetic molecules), and experimental physicists (characterization of the modelled systems and actual implementation of quantum algorithms). We mention among the Theoretical physicists: E. PAVARINI (Forschungszentrum Jülich), A. LUNGHI (U. Dublin), I. TAVERNELLI (IBM Zurich), S. WIMBERGER (U. Parma), D. ZUECO (U. Zaragoza); Chemists: A. PAINELLI (U. Parma), R. SESSOLI (U. Florence), R. WINPENNY (U. Manchester); Experimental physicists: R. BITTL (FU Berlin), L. DA COSTA PEREIRA (KU LEUVEN), F. LUIS (CSIC Zaragoza), M. WASIELEWSKI (Northwestern U.).

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

### **European Projects**

- “CASTLE (Chirality and Spin Selectivity in Electron Transfer Processes: from Quantum Detection to Quantum Enabled Technologies, Horizon Europe, GA 101071533). ERC-SyG, PI Stefano Carretta (Uni Parma). Role of the research team in the project: theoretical modeling, DFT calculations, numerical simulations, design of experiments on real systems, design of schemes of quantum technologies, NMR experiments.
- “Coherent addressing of isotopically pure lanthanide complexes by photons and efficient quantum error correction for Quantum Information Technologies”. Novo Nordisk Foundation, grant NNF21OC0070832, call “Exploratory Interdisciplinary Synergy Programme 2021”. PI: Stergios Piligkos

(Uni Copenaghen), co-PI Stefano Carretta (UNIPR). Role of the research team in the project: theoretical modeling, numerical simulations, design of experiments on real systems, design of schemes of quantum technologies NMR experiments.

### ***National projects***

- NQSTI, National Quantum Science and Technology Institute. Consortium of universities and industries funded by the National Recovery and Resilience Plan, PI for Uni Parma Stefano Carretta (UNIPR). Role of the research team in the project: theoretical modeling, DFT calculations, numerical simulations, design of experiments on real systems, design of schemes of quantum technologies, NMR experiments.
- CROQUET (Molecular Dimers for Quantum Error Correction on the surface, PRIN national project). PI Lorenzo Poggini (CNR-ICCOM), co-PI Elena Garlatti (UNIPR). Role of the research team in the project: theoretical modeling, numerical simulations, design of experiments on real systems, design of schemes of quantum technologies NMR experiments.

## Doctoral Position

### **Artificial Intelligence to support manufacturing through production efficiency, quality and strategies of maintenance**

## Doctoral Programme

Mechanical Engineering

## Description of the doctoral position's main topic

In the current industrial landscape, the integration of artificial intelligence (AI) algorithms has proven to be crucial for the development of competitiveness in industrial entities. This project aims to develop and implement a series of AI algorithms aimed at supporting production, improving product quality, and ensuring the safety of operators and facilities.

### Project Objectives:

- Develop AI algorithms for production optimization, reducing downtime and maximizing resource utilization.
- Implement AI algorithms to improve product quality, reducing defects and increasing reliability.
- Create AI systems for workplace safety management, preventing accidents and reducing risks for operators and facilities.

### Methodology:

- Collect and analyze data related to production processes, product quality, and safety incidents.
- Identify and develop the most suitable AI algorithms to address specific challenges in production, quality, and safety.
- Integrate and implement developed algorithms in a real-world industrial test case.
- Test implemented algorithms in a real environment, gather feedback, and optimize performance.
- Constantly monitor the effectiveness of implemented algorithms and make improvements based on emerging challenges.

### Expected Results:

- Improvement in performance and product quality, with reduced defects and increased reliability.
- Increase in workplace safety, with better ability to intervene in critical safety conditions.

The integration of artificial intelligence algorithms into production processes offers a significant development opportunity for local businesses (e.g., companies in the medical or packaging sector) by supporting production, improving product quality, and ensuring workplace safety. This leads to significant benefits for businesses and society as a whole.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Simone Cinquemani, Marco Belloli, Hermes Giberti

### Doctoral candidate's desirable skills and competences

#### ***Scientific and technical skills***

The candidate must have basic knowledge in the industrial machinery sector. Must have basic knowledge of machine learning and know how to use the main software for programming (Python, Matlab).

### Description of the research group(s) in which the doctoral candidate will be integrated

The research group within which the candidate will work is composed of professors, researchers, and post-docs with experience in the development and implementation of artificial intelligence algorithms in the manufacturing industrial world. In this context, the research group has active collaborations with major industrial players in the packaging and automatic machine design sectors. Currently, ongoing research focuses on the use of machine learning and deep learning algorithms for modeling complex industrial processes, for analysing data related to machine status to develop advanced maintenance strategies, and for real-time analysis of features considered essential to ensure the quality of processed products. In this regard, the research group has numerous publications presented at international conferences and published in specialized scientific journals.

### Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

All doctoral students in the Department of Mechanics of the Polytechnic of Milan have full access to the research laboratories (<https://mecc.polimi.it/ricerca/laboratori-interdipartimentali>) and the instrumentation necessary to conduct experimental activities. The experimental research activity is fully supported by specialized laboratory technicians.

The Department has a dedicated computing centre and has active agreements with Cineca for the use of additional infrastructures if greater computing power is needed.

## Collaboration networks involving the research team

The research activity is conducted in synergy with one of the largest industrial companies in the Emilia Romagna region and in the country. The Coesia Group, and all the companies it belongs to or participates in, actively collaborates with the research group and is actively involved in the development of the project. Coesia is a group of companies for industrial solutions and packaging, based in Bologna.

Coesia includes twenty companies: Acma, Atlantic Zeiser, Cerulean, Cima, Citus Kalix, Comas, Emmeci, FlexLink, G.D, GDM, GF, Hapa, MGS, Molins, Norden, R.A Jones, Sasib, System Ceramics, Tritron, Volpak. The market segments affected are: automatic machines, materials and industrial process solutions.

The Group is present in 36 countries through 84 production plants in 133 operating units. With 8,000+ collaborators, Coesia recorded a turnover of 2,015 million euros in 2022.

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- "Shape-Memory-Alloy Meta-Composites", funded by US Office of Naval Research (grant N00014-20-1-2608) P.I. Simone Cinquemani, funded with 0.7 M€ to develop ML-based algorithms to improve the use of SMA.
- "National Research Centre for Agricultural Technologies", funded by PNRR program, P.I. Simone Cinquemani (Scientific Responsible for PoliMI in Spoke 3), funded with 2.1 M€ to explore the use of hyperspectral images and Artificial intelligence to improve quality in crop production

UNIVERSITÀ DI BOLOGNA (UNIBO)

Combining Machine Learning and Computational Chemistry to explore the chemical space of functional materials

## Doctoral Position

**Combining Machine Learning and Computational Chemistry to explore the chemical space of functional materials**

## Doctoral Programme

Industrial Chemistry

## Description of the doctoral position's general/main topic

The proposed project will necessarily aim at combining computational chemistry (CC) to artificial intelligence / machine learning (ML) on target energy-related applications concerning photoactive organic materials (see subthemes) with a focus on the production and management of large amount of data (BD). Creating new molecules according to specific functional requirements has been the dream of chemists and industries for decades. Today, with the improvements of first-principle packages, AI, and hardware, this might be possible. The future of material research is for molecules to be pre-designed on a computer for fitting a specific purpose, more than checking their chemical-physical properties and then finding a role for them.

The challenges and the benefits of the approach have been nicely reviewed by Tkatchenko and coworkers (<https://doi.org/10.1021/acs.chemrev.1c00107>):

1. Reliance on ML in CC algorithms must be increased:
2. More general ML approaches are needed
3. ML representations must include the right physics
4. CC + ML applications need to strive toward achieving realistic complexity
5. Much more comprehensive data sets (BD) need to be assembled and curated
6. Bolder and deeper explorations of chemical space (BD) are needed.

The successful applicant is expected to contribute to the progress of the field along all these directions.

Just to make a few, non exhaustive examples, possible activities could be the development of:

1. digital platforms for the computational design of a certain class of molecules
2. AI-based generator models capable of cleverly proposing new molecular structures exploring the full chemical space of the targeted compounds.

3. automated workflows to predict with computational chemistry methods the physical properties of different candidate molecules in gas and liquid phase, and in solution.
4. automated algorithms for interrogating (data-mining) existing computational materials repositories (see e.g. <https://cmr.fysik.dtu.dk/> <https://docs.iochem-bd.org/> <https://next-gen.materialsproject.org/> <https://www.materialscloud.org/home> <https://cpd.chemcatbio.org/> <https://www.catalysis-hub.org/> <https://opencatalystproject.org/> ) or literature sources.
5. descriptors and standards for the representation of the chemical data, i.e. the database design.

These developments will be of interest for introducing digitalization (Industry 4.0) in several business sectors at the interface between chemistry, energy, and engineering, such as chemical companies implementing computational solutions for molecular design, and manufacturers producing and marketing the target technologies. Moreover, the project will advance the European scientific basis, and fostering its leadership and global role in the area of renewable energy, in this way supporting EU goals for climate protection, energy independence and economic growth.

### Sub-themes of the doctoral position's main topic (if any)

We singled out three possible subthemes / application fields which are of great interest for the researchers of the department of industrial chemistry:

1) Molecular solar thermal fuels (<https://doi.org/10.1016/j.joule.2021.11.001>): MOSTs are photoswitchable molecules that can store the energy from the sun ("Solar-to-X") and deliver it back as heat in a reversible way. These systems, upon light absorption, can interconvert from a thermodynamically stable isomer A into a higher energy metastable isomer B. The thermal or catalytic B->A back-conversion process can release a certain amount of heat (the energy difference between A and B photoisomers). If this heat release can be controlled, it can be exploited in several technologies, for instance for domestic heating, however materials and devices need further development to meet market requirements and the efficiency range achieved by current solar cells.

2) photoactivated artificial molecular motors (<https://doi.org/10.1021/jacsau.3c00089>): Here the focus, rather than in storing chemical energy for a later release, is the accurate control of long-range motion at the molecular scale, which holds great but still unfulfilled potential for the development of ground-breaking applications in energy storage and bionanotechnology.

3) organic photoredox catalysis (<https://doi.org/10.1021/acs.chemrev.6b00057>): photocatalysis has become a powerful strategy for constructing extensive collections of biologically relevant molecules and complex natural products. Additionally, combining photocatalysis with other catalytic methods has provided novel transformations in the arsenal of organic and industrial chemistry. However, much work remains in developing photocatalysts with higher stability, activity, and performance, including exploring (or avoiding) metals and metal–ligand combinations, as well as novel organic chromophores.

## Potential Supervisors

Luca Muccioli, Ivan Rivalta, Marco Garavelli, Artur Nenov

## Doctoral candidate's desirable skills and competences

- Computational skills and a passion for computer science and modelling are a must, as the PhD will involve a significant amount of coding (mostly in Python).
- -experience in high performance computing and in ML/AI methods
- familiarity with basics of mainstream programming languages (e.g., C/C++, Fortran9X, Java, Python)
- -experience in molecular modelling
- good communications skills, scientific curiosity, and interest in interdisciplinary research

## Description of the research group(s) in which the doctoral candidate will be integrated

The SC2 group specializes in Computational Photochemistry, Photophysics and Spectroscopy of Photoresponsive Molecular Materials, and Computational Materials Science. This includes i) the development and application of computational tools for modelling accurate photoinduced dynamics of complex photoresponsive molecular systems in realistic conditions, including their underlying multi-pulse transient spectroscopies at various spectral regimes, spanning the NIR-VIS-UV-Xray spectral window ii) the characterization and analysis of photoactive molecular materials (from simple isolated molecules to biological photoreceptors and complex molecular architectures including environment effects) is employed for the design of novel and smart materials (e.g., photochromic systems, molecular switches, etc.) with tailored properties, encompassing a tunable photophysics and a controlled (photo)reactivity. iii) the prediction of structural, electronic, and chemical properties of functional materials, including organic soft matter, biological systems and catalysts, through computer simulations (Molecular Dynamics, Metropolis and Kinetic Monte Carlo) methods, quantum chemistry calculations and network analysis.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The computational chemistry group provides the required expertise of an array of quantum and classical calculation and simulations techniques, in computer programming, and the computational resources. The local computer center, fully dedicated to the computational chemistry unit, hosts most recent HPC clusters (~2000 cores) and computational chemistry software (Gaussian, Molcas, Molpro, Amber, NAMD, VASP, QuantumEspresso, etc.).

## Collaboration networks involving the research team

The group has established collaborations with the local experimental groups listed below, to not mention a large network of national and international collaborations:



- Center for Light Activated Nanostructures <https://centri.unibo.it/clang/en>
- Organic Catalysis Structural Analysis <https://site.unibo.it/organic-catalysis-structural-analysis/en>
- Catalysis for Renewable and Innovative Process “Care in Process” group: <https://site.unibo.it/catalysis-for-renewables-and-innovative-processes/en>
- Center for Chemical Catalysis <https://centri.unibo.it/c3/en>

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- GEM – GETting the MOST out of the sun – IFAB foundation project <https://www.ifabfoundation.org/ifab-activities/projects/gem-getting-the-most-out-of-the-sun/> PI Luca Muccioli
- SimDOME – Digital Ontology-based Modelling Environment for Simulation of materials – H2020. <https://simdome.eu/> PI Marco Garavelli

## Doctoral Position

### **Systems for the operation of power distribution networks in the presence of communities of electricity producers and consumers**

## Doctoral Programme

Biomedical, Electrical and System Engineering

## Description of the doctoral position's general/main topic

The project aims to develop models and tools for the analysis and operation of energy distribution networks to address the new requirements and regulatory framework in the sector. The new requirements are mainly due to the expected electrification of private mobility, through increased use of electric vehicles, as well as the growing installation of heat pumps in the civil and tertiary sectors. The new regulatory framework aims to promote the development of energy communities to optimize local balancing between renewable energy generation and consumption, also through direct energy exchanges among end-users. The project is divided into 4 main parts: a) models of aggregators for numerous EV charging stations located in parking lots and/or of district heating systems equipped with heat pump systems; b) models of energy communities; c) models and tools for the analysis of the distribution network in the presence of aggregators and energy communities; d) optimization procedures for the operation of distribution systems in the new regulatory framework, including the acquisition of ancillary services. Parts a) and b) provide the representation of the flexible operation of some systems and energy communities necessary for system operators for the analysis of the network, its optimization, and control. These models will quantify the active and reactive power flexibilities that can be provided by both single users and communities following the requests of distribution and transmission network operators, through participation in local ancillary service markets. Parts c) and d) focus on the analysis and optimization of the distribution system, to exploit the active and reactive power flexibility services. The goal is to maintain the system in efficient and safe operating conditions, particularly regarding voltage deviations, through the control of generation and consumption and the action of specific components (such as transformers equipped with on-load tap changers and reactive power compensators). After faults or in case of high load (e.g., caused by simultaneous charging of many electric vehicles), it is also necessary to manage the congestion of network branches by the distribution network operator. Specific optimization models will therefore be developed for the operator-community interface. Planned activities include the definition of realistic case studies and validation, carried out throughout the project duration, supported by relevant information on real systems and scenarios. The topics are of interest in the international context.

The carrier opportunities refer to engineering and research activities in the design and operation of electrical power systems, with particular reference to distribution networks.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Alberto Borghetti, Carlo Alberto Nucci, Fabio Napolitano, Fabio Tossani

### Doctoral candidate's desirable skills and competences

Knowledge of electric power systems (necessary requirement).

Knowledge deemed useful refers to the use of optimization and simulation tools for the representation of power distribution networks.

### Description of the research group(s) in which the doctoral candidate will be integrated

The Power Systems Engineering Laboratory - LISEP - is part of the Department of Electrical, Electronic and Information Engineering (DEI) of the University of Bologna. The laboratory carries out research in the areas of production, transmission, distribution and utilization of electricity with particular reference to smart grids. Starting from 1994, the laboratory is headed by prof. Carlo Alberto Nucci. The scientific activity is carried out in the framework of the programmed activities of the Italian University power system group and within the framework of several national and international research collaborations. The scientific activity is also connected with that of Cigré working groups of SC 4 System Technical Performance and IEEE PES, as well as with that of the IEEE PES Italian chapter. Besides the presentation to national and international conferences and the publication in scientific journals, the diffusion of the results obtained by the research activity is helped by the participation of LISEP to the EES-UETP (Electric Energy Systems - University Enterprise Training Partnership), which is an Association of Universities and Enterprises for the training in the field of Electric Energy Systems. The research activity is funded by University, MIUR, and EU grants, research contracts with national and foreigner research centres and with private companies. Courses taught in English: CLIMATE NEUTRAL SMART CITIES AND ENERGY COMMUNITIES, ELECTRIC POWER SYSTEMS, ELECTRICAL POWER SYSTEMS FOR SMART CITIES, ELECTRICAL POWER SYSTEMS FOR SUSTAINABLE MOBILITY, SMART GRIDS FOR RENEWABLES INTEGRATION. Additional information and the list of publications is available in the web site <https://site.unibo.it/lisep/en>.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The laboratory LISEP is equipped with computer facilities, adequate software, a real time digital simulator, controllers, a physical medium voltage (15 kV) microgrid with voltage regulator, vacuum circuit breaker and sensors.

## Collaboration networks involving the research team

There are active research collaborations with some Italian universities (Genova, Politecnico di Milano, Cagliari, Salerno, Cassino, Palermo) and foreigner universities (EPFL - Switzerland, South China University of Technology)

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

Ongoing projects: H2020 PROGRESSUS (<https://progressus-ecsel.eu/>) “Highly Efficient and Trustworthy Electronics, Components and Systems for the Next Generation Energy Supply Infrastructure” (2021 – 2023) (PI for UniBo Aldo Romani).

Followed by H2020 ECS4DRES “Electronic Components and Systems for flexible, coordinated and resilient Distributed Renewable Energy Systems” just approved (2024-2026).

H2020 STORE2HYDRO “Novel long-term electricity storage technologies for flexible hydropower”, started Dec. 1, 2023, duration 48 months (PI for UniBo Vittorio Di Federico).

PRIN 2022 S.O.S. MOBILITY - Smart and/Or Sustainable Mobility: when is smart mobility sustainable for consumers and SMEs? (PI Chiara Alvisi). Moreover the laboratory LISEP has participated in the projects GECO (<https://italy.climate-kic.org/projects/geco-green-energy-community/>), PODCAST <http://www.podcast-csea.it/>, SELF USER (<https://www.art-er.it/2020/10/self-user-la-comunita-energetica-sperimentata-in-condominio/>)

Numerical downscaling at the local microscale for the evaluation of climate change adaptation and mitigation measures

## Doctoral Position

### **Numerical downscaling at the local microscale for the evaluation of climate change adaptation and mitigation measures**

## Doctoral Programme

Future Earth, Climate Change and Societal Challenges

## Description of the doctoral position's general/main topic

The research project focuses on the development of downscaling procedures from synoptic to micro-meteorological scales. The state-of-the-art research in the field of developing measures for mitigating and adapting to the effects of climate change has seen extensive use of numerical simulation technology, both in terms of forecasting derived environmental and socio-economic risks, and in assessing the effectiveness of possible countermeasures to be taken to deal with these risks. The decade-long development of numerical modelling techniques has fostered the availability of increasingly reliable tools for climate predictions and projections at global or synoptic scales; however, the question of how to project this information through downscaling procedures to smaller scales and in particular regional scales (~10 km) and local microscales (~1 km) still remains open. In particular, the downscaling of synoptic scales to local microscales is of the greatest importance from the perspective of environmental risk assessment and the effectiveness of mitigation and adaptation measures, especially in urban settings, and for which there is a knowledge gap in the current literature. This is crucial to deliver authoritative and usable environmental and climate information that is relevant at the local scale where actions are planned and implemented.

This project aims to address this issue by developing a general methodology, modelling and numerical tools to downscale climate outputs on the local microscale in order to assess the risks associated with climate change. The winning candidate will use state-of-the-art models for meteorological forecasting (e.g. WRF software) and computational fluid dynamics (e.g. OpenFOAM software).

The project itself has a multidisciplinary component and involves expertise in climatology, meteorology and the physics of small-scale atmospheric processes. It is planned to involve the Atmospheric Physics group in which these competencies are represented. The scientific skills required are mainly meteorological, with a solid knowledge base in the discipline and excellent skills in the use of the Weather Research and Forecasting (WRF) model as well as of computational fluid dynamics (CFD).

## Sub-themes of the doctoral position's main topic (if any)

None

## Potential Supervisors

Silvana Di Sabatino, Carlo Cintolesi, Paolo Ruggieri

## Doctoral candidate's desirable skills and competences

The ideal candidate has a solid background in atmospheric physics and dynamics. Generic competencies in geophysics and environmental sciences are valuable. Basic knowledge of numerical methods, general circulation models, regional climate models and/or computational fluid dynamics are valuable. Similarly, specific expertise with downscaling models and tools and familiarity with gridded observations and climate model data are welcome.

Additional valuable skills include familiarity with C++, Python or similar languages, and FORTRAN.

## Description of the research group(s) in which the doctoral candidate will be integrated

The collaboration and support of other researchers in the group of Atmospheric Physics with expertise in microscale simulations and climatology will be crucial for achieving the project goals. The work done by the group attempts to further the understanding of fundamental issues related to the dynamics, radiative transfer and thermodynamics of the atmosphere. The goal is to improve our knowledge of key processes regulating the evolution of the terrestrial atmosphere, both in the short-term (meteorology) and long-term (climate). Interest is devoted to the development of novel parameterizations (in the lower and higher atmosphere) for improvement of numerical (NWP) weather prediction models. To this end, the research performed by the Group employs a variety of state-of-the-art scientific investigation techniques including large scale field measurements (both in urban context and in the natural environment), numerical modelling and simulation, development of new satellite missions, novel interpretation of existing data sets. The Group is also involved in the definition of innovative methods to extract the maximum information content from in-situ and remote sensing measurements of the atmosphere either from active or passive sensors, with the aim to improve the knowledge of clouds and precipitation physics.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The doctoral candidate will have access to data storage capabilities and computing resources provided by the Open Physics Hub (OPH, <https://site.unibo.it/openphysicshub/en>). OPH is a hub established by the Department of Physics and Astronomy that provides a HPC cluster called 'Matrix'. Matrix features 1952

virtual cores with 4 GB RAM/core and 500 TB of disk storage space. The hub also provides facilities for acquisition and installation of additional dedicated storage.

The group will provide access to a suite of geophysical numerical models, namely: the SPEEDY-NEMO model, an intermediate-complexity atmospheric GCM, that can be coupled with a slab-ocean model or with the NEMO ocean model and the OPEN-IFS, the open version of the ECMWF operational Integrated Forecast System, that is a state-of-art atmospheric GCM.

The candidate will have access to the WRF (Weather Research and Forecasting) model, developed by the National Center for Atmospheric Research (NCAR) and designed for both research and operational purposes. Finally, OpenFOAM, which is an open-source software for computational fluid dynamics, written in C++ and provided with a large number of modules for simulating a variety of thermo-fluid flows at high resolution.

The proposed thesis topic is part of an international scientific collaboration (see research projects with European funding linked to it) and currently constitutes one of the frontier topics in the field of weather-climate research.

## Collaboration networks involving the research team

The group has several collaborations at the national and International level, mainly through the coordination and participation on several international projects.

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

The activities are tightly related to the scientific agenda of the project TRIGGER (SoluTions foR mltiGatinG climate-induced hEalth thReats), Horizon-Europe 2022-2027, PI prof. Silvana Di Sabatino. TRIGGER has the main objective to ' identify, monitor and quantify direct and indirect impacts of climate change induced environmental hazards on human health through the direct collection of health, weather-climate, environmental and socio-economic data with user-friendly tools (sensors, simplified models, and data hub).'' The project addresses this objective by conducting transdisciplinary investigations, integrating knowledge and translating it into practical know-how and workable tools. The research outcomes of the project (data, tools and applications) are finally integrated into a novel platform, the Climate Health Connection Hub, built with a multidisciplinary and participatory approach.

The activities are relevant for the ALBATROSS project, Horizon-Europe 2023-2027, PI prof. Laura Sandra Leo, co-PI prof. Silvana Di Sabatino. ALBATROSS aims at delivering novel, innovative and decision making-relevant tools and knowledge which will support the adoption of feasible, effective, and sustainable need-based adaptation strategies into AF policies and programs. It will do that by co-creating climate services and tools which will enable the weighting of compound and cascading impacts (benefits and threats) on ecosystem

health, food security, socio-economic vulnerability while addressing specific natural hazards (e.g., drought or flood) or sectoral climate adaptation needs (e.g., agriculture) through nature-based solutions (NBS) and other climate adaptation measures.

The activities are relevant for the RISKADAPT project, Horizon-Europe 2023-2026, PI prof. Silvana Di Sabatino. RISKADAPT will provide, in close cooperation with the end-users/other stakeholders, a novel, integrated, modular, interoperable, public and free, customizable user-friendly platform, to support systemic, risk-informed decisions regarding adaptation to Climate Change induced compound events at the asset level, focusing on the structural system. The activity of UNIBO is to perform high-resolved simulations of tall buildings exposed to high wind and wind-driven rain, also including input from downscaling (from WRF to CFD), to estimate the exposure to natural hazards and the structure vulnerability.



## Doctoral Position

### **Satellite insights: Socio-economic data for Sustainable Development**

## Doctoral Programme

Environmental Sustainability and Wellbeing

### Description of the doctoral position's general/main topic

The increasing frequency and intensity of natural disasters such as floods, wildfires, hurricanes, and earthquakes, requires an investment to understand their impacts on society. Infrastructure, encompassing roads, bridges, buildings, and utilities, serves as the backbone of modern societies, facilitating economic activities, transportation, energy production, and communication networks. However, these critical assets are vulnerable to damage and destruction when exposed to natural forces. In this context, the present Ph.D. project proposes to leverage remote sensing and satellite data to assess the socio-economic consequences of natural disasters. The research aims to develop innovative methodologies integrating advanced techniques in remote sensing, machine learning, and socio-economic analysis to comprehensively understand the impacts of natural hazards on communities, economies, and the environment. By analysing satellite imagery, alongside socio-economic indicators, the project seeks to provide insights into the resilience of communities and the effectiveness of disaster management strategies. Moreover, this approach enables the detection of land cover changes, urban sprawl, and population density patterns over time, providing crucial information for assessing vulnerability and exposure to natural disasters of specific areas. By integrating socio-economic data, it becomes feasible to understand the underlying drivers of population growth and urbanization in high-risk areas, including factors such as employment opportunities, housing affordability, and land-use policies.

The core objective of this Ph.D. project is to exploit remote sensing and satellite data techniques to study and develop new socio-economic indicators that offer a comprehensive understanding of the dynamics between human activities, environmental factors, and economic development in various geographical areas. In addition, the project aims at (i) developing methodologies for detecting and mapping natural disasters using remote sensing and satellite data, (ii) quantify the socio-economic impacts of these disasters on affected regions, (iii) investigate the vulnerability and resilience of communities to natural hazards, (iv) assess the effectiveness of disaster response and recovery efforts, and (v) provide evidence-based recommendations for enhancing disaster preparedness, risk reduction, and resilience-building strategies at local, national, and international levels.

By understanding the complex interplay between natural processes, built environments, and human activities, we can develop more effective strategies for disaster preparedness, response, and recovery, ultimately informing evidence-based decision-making for disaster risk reduction and resilience-building and sustainable development in vulnerable communities.

Graduates are poised for a multitude of promising career pathways. They may pursue roles as research scientists in academia or other research institutions, contributing to cutting-edge research in fields such as environmental science, urban planning, and disaster management. Alternatively, opportunities as data analysts or GIS specialists in private sector companies, consulting firms, or non-profit organizations, may be exploited.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Nicolò Barbieri, Massimiliano Mazzanti, Francesco Nicolli

### Doctoral candidate's desirable skills and competences

The successful candidate for the doctoral project must possess the will to develop an interdisciplinary background for his/her future career. Proficiency in handling economic data and interpreting research findings accurately is a plus. Additionally, basic programming skills are required for data manipulation and analysis. Familiarity with research methodologies and excellent communication skills, both written and oral, are indispensable for presenting research findings and engaging with colleagues and stakeholders effectively. While advanced skills such as knowledge of machine learning techniques, database management, spatial analysis, policy analysis, and interdisciplinary collaboration are advantageous, they are not mandatory prerequisites. However, candidates will have opportunities to develop these skills through coursework, workshops, and self-directed learning during their doctoral studies.

### Description of the research group(s) in which the doctoral candidate will be integrated

The doctoral candidate will join the dynamic research group of SEEDS (Sustainability, Environmental Economics, and Dynamics Studies), a leading research center in environmental economics as well as an esteemed interdepartmental research center dedicated to interdisciplinary inquiry at the nexus of economics, social science, and statistics/econometrics. SEEDS employs empirical methodologies to scrutinize the sustainable transition, with a keen focus on facets such as technological advancement, organizational dynamics, individual behaviours, labor markets, and geographical considerations. The SEEDS research group is characterized by a deep expertise and diverse skill set at the forefront of interdisciplinary research. Comprising individuals adept in econometric analysis, statistical modelling, and programming languages, the

team is well-equipped to tackle complex socio-economic challenges. Their proficiency in handling large datasets and employing rigorous empirical methodologies underscores their commitment to producing high-quality research outcomes. The group's track record includes impactful studies elucidating the effects of government policies on economic growth, rigorous analyses of income inequality drivers, and insightful assessments of labor market dynamics and employment trends. Such accomplishments underscore the team's dedication to advancing knowledge and informing evidence-based decision-making in economics and social sciences. SEEDS also demonstrates a strong commitment to regional studies, extending its interdisciplinary approach to address pressing environmental concerns. Currently, the group is embarking on a pioneering project aimed at quantifying the intricate relationship between pollution levels and economic growth within specific regions. Leveraging advanced methodologies in remote sensing, spatial analysis, and econometric modelling, the project seeks to unravel the complex dynamics underlying environmental degradation and its impacts on regional economies. By integrating satellite data with socio-economic indicators, the team aims to provide novel insights into the trade-offs between industrial development and environmental sustainability. This innovative endeavour underscores SEEDS' dedication to addressing multifaceted challenges at the regional level, further to improve the expertise within the research center in the field of sustainability and environmental economics. For further details on SEEDS, encompassing ongoing research endeavours, publications, and team composition, please visit: <https://www.sustainability-seeds.org/>.

### Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The doctoral candidate will have access to state-of-the-art facilities and resources to conduct their research. Unife has access to extensive datasets relevant to various economic research topics. These datasets may include economic indicators, surveys, administrative records, and other sources of economic data. The candidate will have access to computing facilities equipped with powerful hardware and software necessary for econometric analysis, statistical modelling, and data visualization. This may include access to statistical software packages such as Stata, R, Python, and MATLAB, as well as performing PCs for handling large datasets. Moreover, the candidate will have access to the university's library resources, which include a vast collection of books, journals, and electronic databases related to economics and related fields. These resources will support literature reviews, background research, and theoretical framework development for the candidate's research. Finally, Unife often provides collaborative spaces where doctoral candidates can interact with faculty members, fellow researchers, and peers. SEEDS organizes workshops, seminars, and training programs on topics relevant to economic research methods, data analysis techniques, and academic writing skills. The candidate will have the opportunity to participate in these events to enhance their research skills and stay updated on the latest developments in the field of economics and social sciences.

## Collaboration networks involving the research team

SEEDS- Unife is an inter-university research centre created in 2013 according to Italian university law to gather the competencies on environmental and sustainability economics of researchers from eight universities. The University of Ferrara is the legal and administrative entity of SEEDS according to the statute of the centre as approved by the partner universities. Since 2014, SEEDS is partner of the EEA's ETC-WMGE (Waste and Materials in a Green Economy), in which it has the leadership of the tasks on the green and circular economy and the macroeconomic sustainability transition. Thanks to its legal and organizational setting, SEEDS can be the entry point to all the competencies available in its eight universities as well as the networks to which the latter belong. The SEEDS team has been involved in a number of activities dealing with assessing the drivers and barriers of sustainability transitions, with special emphasis on policy issues. Activities consisted in analytical work at different levels of aggregation (micro-meso-macro), using a variety of analytical tools. Researchers in the SEEDS team have published a number of academic articles on policy, regional studies and innovation topics and were involved in various related EU-funded research projects, always in connection to the analysis of innovation diffusion and dynamics, policy assessments at macro, meso and micro levels.

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

Horizon "ST4TE: Strategies for Just and equitable Transition in Europe", HORIZON-CL2-2023-TRANSFORMATIONS-01. European Commission. 2024-27

- Project title: "RE-ADJUST: REgional Assessment of Distributive impacts of a JUst and Sustainable Transition" 2023-2026, Progetti di ricerca di Rilevante Interesse Nazionale.
- Project title: 2022-2026 (European Topic centre on circular economy). It is a framework partnership agreement to support the EEA activities. Leader VITO (BE), Funded by: European Environmental Agency.
- Horizon FUTURESILIENCE: Coordinated by European Future Innovation System (EFIS) Centre (Belgium), (UNIFE partner) 2022-25
- Horizon SUSTRACK: Supporting the identification of policy priorities and recommendations for designing a sustainable track towards circular bio-based systems" (UNIFE partner, coordinated by UNITELMA Rome); 2022-25

## Doctoral Position

### Data Science for Sustainable Mobility

## Doctoral Programme

Computer and Data Science for Technological and Social Innovation

### Description of the doctoral position's general/main topic

Urban mobility plays a critical role in shaping urban life in all countries in the world. It exhibits challenges that are hard to address and often are solved without a scientific approach. The intricate web of transportation systems, including road networks and public transit, not only influences the efficiency of daily commutes but also has far-reaching implications on environmental sustainability, energetic sustainability, air quality, and the overall quality of life for citizens. The delicate balance required to ensure smooth urban mobility is often disrupted by factors such as traffic congestion and the environmental toll of excessive vehicular activity. As cities continue to grow and evolve, addressing the complexities of urban mobility becomes imperative for fostering sustainable, accessible, and liveable urban environments. In this context, smart mobility has the potential to enhance street safety as well as the driving experience in smart cities, whose streets will be soon populated by autonomous vehicles.

To reach this goal, the implementation of smart mobility requires not only a robustly connected infrastructure connecting vehicles and their environment but also appropriated algorithms and methods for effective management and coordination of vehicle movements. Indeed, road traffic is an extremely complex system and intersections, in particular, pose a significant challenge: a delicate balance is required between assigning priority in a fair way and the flexibility needed for emergency situations. Traditional solutions involve traffic yield rules, traffic lights, and roundabouts that are used to address the unpredictable nature and reaction times of human drivers, as well as the characteristics of the intersections (e.g., yielding to larger and more heavily trafficked lanes). These solutions, however, are not always the best-performing ones, as demonstrated by the frequent traffic jams occurring in our cities.

The goal of this project is to study infrastructures and algorithms that take advantage of the analysis of data to improve the sustainability of mobility, in particular in the urban context.

At the end of the project, the PhD student will have acquired knowledge and skills about the management of complex systems (such as urban mobility scenarios) by defining algorithms that start from the data and define strategies. These knowledge and skills open carrier opportunities in research centres, in universities, in

private complex companies, and in public administration, in which the topics of software development, system engineering, system management are addressed.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Cabri Giacomo, Capodieci Nicola, Marongiu Andrea, Montangero Manuela

### Doctoral candidate's desirable skills and competences

- Software programming
- Data analysis

Useful skill requirements:

- Knowledge of modern heterogeneous, multi-core system on chip architectures
- Knowledge of parallel programming
- Advanced mathematics
- Energy sustainability
- Environmental sustainability
- Software engineering

### Description of the research group(s) in which the doctoral candidate will be integrated

The hosting Department for the research project includes several research groups, each working in cooperation with international companies and research centres. Besides specific skills that can be browsed accessing the research groups Web pages, a wide range of research and technology transfer activities is performed in highly interdisciplinary areas. For example, research on real-time systems and on next generation embedded platforms has been exploited to create autonomous driving and data analytics systems; the analysis of large amounts of data helped the interpretation of socio-technological systems (social media, but also economic innovation systems) or supported initiatives in the personalized medicine domain; adaptive and autonomous systems can be distributed (pervasive computing) and be an integral and active part of "Smart cities" paradigms; artificial systems can evolve and improve their performance to better serve citizens; cryptography has been used for understanding the mechanisms of genetics. In particular the Department has a strong background in the following areas:

- High-Performance Real-Time Systems (<https://hipert.unimore.it/>)
- Intelligent and distributed systems (<http://www.agentgroup.unimore.it/>)
- Data management and analytics (<https://www.isgroup.unimo.it/>)

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The PhD student can access the computer laboratories of the department and exploit the existing servers with simulation software. The MASA area in Modena (<https://www.automotivesmartarea.it/?lang=en>) can be exploited for experiments on the field. The PhD student can also exploit some reduced-scale vehicles to perform in-lab real experiments.

## Collaboration networks involving the research team

The research group has research collaborations with the following universities/research centres:

- BIBA – Bremer Institut für Produktion und Logistik, Germany, <https://www.biba.uni-bremen.de/en.html>
- Department of Service Computing, University of Stuttgart, Germany, <https://www.iaas.uni-stuttgart.de/en/department-service-computing/>
- IHMC - Institute for Human & Machine Cognition, USA, <https://www.ihmc.us>
- Motivational Digital Systems (MoDiS) research unit of the Bruno Kessler Foundation (FBK), Trento, Italy, <https://modis.fbk.eu>

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- WASABI (White-label shop for digital intelligent assistance and human-AI collaboration in manufacturing). Funding scheme: HORIZON Innovation Actions Website: <https://wasabiproject.eu/>. Principal Investigator: BREMER INSTITUT FUER PRODUKTION UND LOGISTIK GMBH (BIBA) – Germany. Role of the research team: Academic partner
- AI4CSM (Automotive Intelligence for/at Connected Shared Mobility). Funding scheme: H2020 ECSEL Research and Innovation action. Website: <https://ai4csm.automotive.oth-aw.de/> . Principal Investigator: INFINEON TECHNOLOGIES AG (Germany). Role of the research team: National Unit Leader, Academic partner

## Doctoral Position

**Exploitation of Big Data from HVAC plants, vehicle systems and sensors, weather stations, ground measurements and satellites to support urban sustainability**

## Doctoral Programme

Ingegneria Meccanica e del Veicolo

## Description of the doctoral position's general/main topic

Urban sustainability faces multifaceted challenges, with energy consumption and urban heat islands (UHI) being critical concerns. Harnessing big data from diverse sources such as HVAC plants, vehicle systems, sensors, weather stations, ground measurements, and satellites offers an unprecedented opportunity to address these challenges comprehensively. This project proposes an integrated data analytics framework to support urban sustainability initiatives with a focus on energy efficiency and UHI mitigation. By integrating data from disparate sources, the aim is to provide actionable insights for policymakers, urban planners, and stakeholders to make informed decisions and implement effective interventions. The following key aspects can be addressed in part or altogether.

1. Data Integration and fusion: Aggregate data from HVAC plants, vehicle systems, sensors, weather stations, ground measurements, and satellites. Develop robust data integration techniques to harmonize disparate data formats and resolutions. Employ advanced fusion algorithms to reconcile conflicting or overlapping information and generate comprehensive datasets.
2. Predictive analytics for energy consumption: Utilize historical data to build predictive models for energy consumption patterns in urban areas. Incorporate real-time data streams to enhance the accuracy and responsiveness of predictive models. Integrate weather forecasts and environmental factors to anticipate energy demand fluctuations and optimize resource allocation.
3. UHI mapping and analysis: Apply remote sensing data from satellites to assess UHI intensity and spatial distribution. Combine ground measurements and sensor data to validate satellite based UHI maps. Identify hotspots and vulnerable areas within the urban landscape for targeted mitigation strategies.
4. Decision support system: Develop a user-friendly interface for visualizing and interpreting analytics results. Provide decision support tools to prioritize interventions based on energy efficiency gains and UHI reduction potential. Enable scenario analysis to evaluate the impact of various policy measures and urban planning strategies on sustainability goals.



5. Stakeholder engagement and knowledge transfer: Collaborate with local authorities, utility companies, and community organizations to ensure the relevance and applicability of research findings. Conduct workshops, seminars, and training sessions to disseminate knowledge and build capacity for sustainable urban development. Foster partnerships for data sharing and collaboration to sustain the project's impact beyond its initial phase.

6. Expected outcomes: Enhanced understanding of urban energy dynamics and UHI phenomena. Data-driven insights to inform policy formulation and infrastructure investments. Reduction in energy consumption and greenhouse gas emissions. Improved urban livability and resilience to climate change. Empowerment of stakeholders through participatory decision-making processes.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Alberto Muscio, Giulio Allesina, Stefano Pedrazzi, Andrea Cimarelli, Enrico Stalio

### Doctoral candidate's desirable skills and competences

General background and basic knowledge of thermodynamics, fluid dynamics and heat transfer as provided in university bachelor and master courses in Engineering, Physics, Chemistry, Environmental Sciences.

Non mandatory: knowledge of programming environments such as Python, Matlab/Simulink, etc.; knowledge of measurement methods and data processing.

### Description of the research group(s) in which the doctoral candidate will be integrated

The candidate will be embedded within a dynamic workgroup renowned for its expertise in pivotal areas crucial to the project's success. Notably, our team has a strong expertise on several key aspects of the project. In first, on the development, optimization and testing of solar reflective materials and other countermeasures to the urban heat island effect. The workgroup operates an ISO/IEC 17025 accredited testing laboratory, EELab, with a strong reputation at national and continental level and close relationships with the industry, as well as with leading national and foreign research groups. A strong expertise exists on the exploitation of renewable sources (photovoltaics, biomasses, etc.), as well as on the assessment and improvement of thermal comfort in the built environment. Energy efficiency of buildings is also a crucial research topic of the workgroup, with the focus in innovative HVAC plants, passive building solutions, innovative materials, exploitation of renewable energy. Close collaborations exist with other workgroup of the same department, working on satellite data analysis, vehicle dynamics, energy systems, material optimization and testing, with several jointly developed research.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

Equipment of the Energy Efficiency Laboratory of the University of Modena and Reggio Emilia, ISO/IEC 17025 accredited laboratory. In particular, advanced instruments for assessment of thermophysical properties (guarded hot plate for thermal conductivity measurement, etc.), surface properties (solar reflectometers, spectrometers and albedometers for solar reflectance; thermal and IR emissometers for thermal emittance, etc.), thermal comfort (multi-sensor stations), temperature fields (contact and noncontact sensors, IR cameras). Calculation servers, programming and simulation software, wide data sets.

## Collaboration networks involving the research team

Prof. Mat Santamouris, Prof. Riccardo Paolini, Univ. of New South Wales, Sydney (Australia)

Prof. Hashem Akbari, Concordia University, Montreal (Canada)

Dr. Ronnen Levinson, Lawrence Berkeley National Laboratory, Berkeley (CA, USA)

Dr. Michele Zinzi, ENEA, Roma (Italy) Prof. Federico Rossi, Prof. Anna Laura Pisello, Univ. of Perugia, Perugia (Italy) Prof. Umberto Berardi, Toronto Metropolitan University, Toronto (Canada)

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

The workgroup has numerous collaborations for scientific and industrial research but not international, national or regional projects activated within the last 5 years and relevant to the Futuredata4EU position. Previously, the group leader, Alberto Muscio, was P.I. of the Project MAIN – Matériaux Intelligent, funded by the Med Programme of EU with a budget 1.87 M€ and focused onto solar reflective materials to counter the urban heat island effect.

## Doctoral Position

### **Beyond Deterministic Models in Smarter Power Electronic Converters for Sustainable Energy Management in Home, Industry and Transportation**

## Doctoral Programme

Information Technology

### Description of the doctoral position's general/main topic

The current targets of sustainability for human activities require a major paradigm shift in all the areas in which energy is generated, processed and used. That is the reason for the deep electrification process which is impacting the modern society. The performance of this electrified energy systems relies deeply on how they are controlled with respect to user intervention and mission profiles; likewise, the self-monitoring of these systems is essential, to guarantee reliability and to reduce operating and maintenance cost.

In this scenario, the power conversion units (power electronic converters, drives, inverters, ...) should be equipped with a certain degree of "intelligence", making them smart systems. Currently, there is a huge potential to improve this "intelligence", since most of the control algorithms still rely on well-established techniques, such as linear control, predefined mission profiles, fuzzy logic, non-linear observers. These techniques are appropriate, but it is believed that the massive progress in AI systems, machine learning and processing of big data can yield to relevant improvements of the electronic power system performance. Additionally, the constantly increasing computational capability of logic controllers opens new possibilities in terms of real-time embedded implementation of complex algorithms (such as neural networks), which was hardly possible before.

Following these strong drivers, this research proposal wants to investigate the application of advanced AI techniques to electronic power conversion systems in use in home, industry and transportation applications. These three areas are aligned with all the main targets at European, national and regional levels. Specifically, better home energy conversion leads to more efficient houses, as well as reduced impact of cities on their surrounding environment. Similarly, industry can get relevant benefits from this approach, since currently most of the motion power in factories is driven by electric motor, and there are relevant possibilities to improve efficiency, reduce faults and operator maintenance as well as improving safety in the workplace. From the regional point of view, Emilia-Romagna hosts many SMEs, which could get enormous advantages from delivering innovative technologies to the market. Transportation is another field in which accurate

forecast of the user behaviour has a revolutionary potential: it could be possible to plan vehicle charging, maintenance, improve the scheduling of public transport, react promptly to traffic disruption and much more.

The potential of this proposal is also in the new figures which can be prepared on the topic of AI techniques for a highly specialized field, such as that of electronic power conversion.

### Sub-themes of the doctoral position's main topic (if any)

The research activity can be split in three major sub-themes.

(1) AI for reliability prediction in power converter and drives: to assess the remaining useful life of safety-critical systems, predicting maintenance and reducing downtime. Current techniques rely on the knowledge of the aging mechanisms, which may not be known; AI techniques, such as unsupervised learning, may find hidden patterns in the data, and discover reliability issues which could be undetectable by humans.

(2) AI and big data for load demand forecast in micro- and nano-grids: the way in which any system is used impacts its performance over time; this is true also for systems used in micro/nano-grids, such as smart chargers, energy storage systems, point-of-load converters. In this case, the anticipated knowledge of the user demand, possibly achieved by training algorithms on big data, will give relevant benefits.

(3) Machine learning for the observation of hidden parameters in electronic power conversion systems: maximising the power density of drives requires a deeper knowledge of their behaviour; big-data-driven models will improve the modelling of the electric motor and open new possibilities for the monitoring of hidden parameters, such as flux quantities or internal temperatures, all affecting the dynamic performance and lifetime of these systems.

### Potential Supervisors

Alessandro Soldati (UNIPR), Carlo Concari (UNIPR), Francesco Iannuzzo (DK), Marco Rivera (UK), Minglei You (UK), Sergio Vazquez Perez (ES)

### Doctoral candidate's desirable skills and competences

The candidate should have some background in the fields of dynamic system modelling and programming; skills in the field of AI, machine learning, embedded programming, control of dynamic systems, reliability modelling are highly appreciated and could boost the output of the research activity under time-limited conditions.

### Description of the research group(s) in which the doctoral candidate will be integrated

PExLab (<https://www.pexlab.unipr.it/>) at the University of Parma investigates the topics of power converters, energy management, drive control and reliability in industrial and transportation applications. The group

participates in several research projects, funded under both public and private money. The active research projects cover the topics of: power conversion for electric vessels, smart and sustainable drives for the industry, thermal management of power electronic components and batteries, optimal energy control in hybrid energy storage systems (both stationary and mobile). The existing skills in the group are: modeling of power converters, modelling of batteries, design of custom power converters and processing systems, development and validation of control algorithms for drives and energy storage systems, reliability investigation for electronics and drives, thermal modelling of power electronic components, development of real-time embedded code for control implementation, model-based design for complex energy systems. PExLab also partners with eDriveLAB, its spin-off company working in the field of vehicle electrification.

### Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

PExLab staff has access to several research facilities: the laboratory itself is equipped with workstations, thermal imagers, high-bandwidth oscilloscopes, data loggers. Additionally, the staff has access to the HPC cluster of the University of Parma (with a specific quota), one temperature-controlled chamber and several testing facilities made available by the eDriveLAB spin-off.

### Collaboration networks involving the research team

PExLab cooperates with various Universities in Europe: (1) Aalborg University, Denmark; (2) University of Seville, Spain; (3) University of Oviedo, Spain; (4) Aalto University, Finland. PExLab cooperation network also includes the Italian Universities of Padua and Cagliari, as well as several local companies interested in the results of the present research.

### International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

\* Highly-integrated all-Electric Propulsion-charging system on zero-emissions TUboats for NExt-generation harbours (NEPTUNE): project funded under the PRIN 2022 program (national, competitive), Alessandro Soldati as principal investigator. FutureData4EU activities are of interest for that project, since the forecast of the load demand and the mission-profile-related aging of the batteries can be profitably done using machine learning and big data techniques, possibly overcoming limitations of the current solutions.

\* Superconducting electric machines and cryogenic power electronics for high-efficiency, reliable and power-dense eENERGY conversion (SYNERGY): project funded under the PRIN 2022 program (national, competitive), Prof. Carlo Concari as principal investigator. FutureData4EU activities are of interest for that project, since poor information is available for reliability of drives in cryogenic conditions.

## Doctoral Position

### **Electric vehicles: Infrastructure system and charging strategies based on Renewable Energy Sources**

## Doctoral Programme

Electrical Engineering

## Description of the doctoral position's general/main topic

Environmental sustainability is a top priority, and innovation in the automotive sector is moving toward environmentally friendly vehicles. Electric vehicles (EVs) represent the new frontier of sustainable mobility, helping to reduce greenhouse gas emissions and promote a cleaner, greener future. Unlike traditional gasoline or diesel cars, EVs are powered by batteries that can be recharged using renewable energy. This aspect not only helps reduce air pollution but also promotes the use of clean and Renewable Energy Sources (RESs). However, to encourage the adoption of EVs, it is crucial to develop a widespread network of charging stations. Many cities are already investing in fast and efficient charging infrastructure that allows electric car batteries to be recharged conveniently and quickly. The focus of this project is on street vehicles and specifically on developing a scalable and effective model to meet people's needs and habits. A city in Emilia Romagna will be taken as a case study, on which by analysing the territory, we will initially assess the current state of diffusion of both Electric Vehicles and charging infrastructure, and from there we will hypothesize a series of scenarios and possible integrations of technologies while balancing the load demand to the electric grid, based on Grid-to-X (V2X).

An optimal sizing and layout method of charging infrastructure, based on a dynamic learning optimization approach, should be used, aiming at minimizing infrastructure and operational costs and maximizing vehicle efficiency and availability. A dynamic analysis of next-generation mobility scenarios that use renewable energy (e.g., photovoltaic systems), adapt to the needs of the urban context, and integrate effectively into the energy distribution network will be carried out.

Finally, it will be possible to consider the implementation of a digital platform that, based on the technical properties of vehicles, traffic data, and energy supply conditions, determines the optimal fleet and infrastructure sizing with associated placement, infrastructure and operational costs, and the optimal charging strategy in a dynamic and adaptive context.

## Sub-themes of the doctoral position's main topic (if any)

None

## Potential Supervisors

Michela Longo; Dario Zaninelli; Sonia Leva

## Doctoral candidate's desirable skills and competences

The candidate must demonstrate the ability to work in a team and use programs such as Python and/or Matlab. Passionate about mobility and demonstrate knowledge in the field.

Knowledge useful but not required

Technical analysis requires a range of mathematical skills, to produce data and model analysis through the use of Machine Learning techniques.

## Description of the research group(s) in which the doctoral candidate will be integrated

The Ph.D. student will join the transport group of the Politecnico di Milano. As the name of the group implies, the main research topic is the area of mobility, particularly rail and road mobility. In fact, some members of the group are experts in the rail field, while other members are experts in the road field. Precisely on this aspect, the analysis is at the macro and micro level, analysing cars, trucks, buses to bicycles, motorcycles and scooters. Where the analysis is just the study of the transition from traditional vehicles to green vehicles. There is intensive research activity on several innovative topics, such as: - Optimization algorithms for the deployment of electric vehicles and charging stations within cities. Study of different scenarios considering also socio-economic and behavioural factors to characterize as realistically as possible the mathematical models used in the algorithms. - Smart Mobility in Smart Cities: sustainability analysis with a focus on the integration of photovoltaic and wind systems with sustainable mobility systems based on electrically driven road and metro vehicles. - Analysis of new technologies to grow the use of electric vehicles, e.g. battery swap, Wireless static and dynamic recharge, Vehicle to Grid (V2G). - Diffusion and integration of renewable energy. - Disturbance characterization and Power Quality analysis in electrical distribution networks characterized by the presence of electric vehicles.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

MultiGood MicroGridLAB (MG2lab): MG2lab includes programmable and non-programmable generation units (solar PV modules, natural gas fired combined heat and power engine), different types of storages and various types of loads representative of the most future on- and off-grid applications for MultiGoods MicroGrids.

Power Electronics for Electric Mobility and Safety (POEMS): New laboratory where there will be driving simulators with optimization algorithms and artificial intelligence, Static WPT Recharge with related car tests, and more.

Availability of data base in order to contextualize the problem and to analyze the data and make a prediction on them. Site visits to the territory in order to understand feasibility, critical aspects and to be able to make something scalable and adaptable depending on the territory under consideration.

## Collaboration networks involving the research team

Considering the research activity to be developed, the doctoral student will be able to take advantage of existing collaborations with which various research activities have been and are being carried out. International universities may be:

- Massachusetts Institute of Technology -Tokyo Metropolitan University
- University of Cadiz- Canmet ENERGY Research Centre - Natural Resources Canada | Government of Canada
- University of MalagaNational universities:-University of Palermo-University of Genoa-University of Trieste
- University of Brescia- University of PerugiaCompanies in the mobility industry:- A2a spa- ATM- Star Mobility
- Autoguidovie- Free2Move- Autostrade per l'italia- BreBeMi

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

MOST - Centro Nazionale per la mobilità sostenibile through collaboration with 24 universities, CNR and 24 large companies, has the mission of implementing modern, sustainable and inclusive solutions for the entire national territory. The areas and technological fields of greatest interest in the project are: air mobility, sustainable road vehicles, water transport, rail transport, light vehicles and active mobility. The National Center will take care of making the mobility system more "green" as a whole and more "digital" in its management. It will do so through lightweight solutions and electric and hydrogen propulsion systems; digital systems for the reduction of accidents; more effective solutions for public transport and logistics; a new model of mobility, as a service, accessible and inclusive. Professor Zaninelli is leader for the Spoke 13 – Electric Traction and Batteries. In this project Professor Michela Longo works in this project and also participated in the drafting of the project with the Dean of Politecnico di Milano. Scientific leader (Michela Longo) of the Milan-Rennes Summer School of Future Green Mobility project. <https://www.eitum.polimi.it/summerschool-milan-rennes-2022/>.



## Doctoral Position

### **The role of digital data in interpreting complex urban phenomena and supporting mobility-related policies**

## Doctoral Programme

Urban Planning Design and Policy

### Description of the doctoral position's general/main topic

A fundamental shift in mobility patterns in recent years is strongly related to innovations in transport supply and services, as well as in the technical and digital data and devices that have revolutionised “shared mobility”, motorised vehicle use, and more in general the organisation of daily mobility practices.

In this frame, the research activity aims to test the usability and relevance of digital, mobile phone data, and other potential sources of big data, to analyse current mobility practices in the urban areas of Emilia Romagna Region and to support mobility-related policies in the field of sustainability, land use, access to housing and main services and social inclusion.

Digital and mobile phone data have been employed in several applications in urban and territorial research over the last fifteen years. Their applications primarily aim at analysing the space-time variability in the population's distribution in cities (Mobile Landscape Method in Ratti et al., 2006; Sevtsuk & Ratti, 2010); classifying different “basic” profiles of city users and patterns of consumption (Reades et al., 2007; Soto & Frías-Martínez, 2011; Järv, Ahas, & Witlox, 2014), studying the trip chaining (Srinivasan & Raghavender, 2006), updating origin/destination matrices and transport models (Noulas, Scellato, Lambiotte, Pontil, & Mascolo, 2012; Shoval & Ahas, 2016; Shoval, Kwan, Reinau, & Harder, 2014; Yip, Forrest, & Xian, 2016), detecting mobility behaviour for demand analysis (Bayir, Demirbas, & Eagle, 2010) and, during the Covid pandemic, for emergency management (Wang, et al. 2020).

These applications allow dealing with the opportunities and the critical issues in the processing of digital and mobile phone records, along with the need for integrating these data with other available data sources to investigate complex urban phenomena. Despite the potential of digital and mobile phone data, related to an unprecedented coverage of population and geographic area, continuous and sufficiently long in the collection periods, and detailed and accurate in the location and motion information (Steenbruggen et al., 2013), the diffusion in the use of them in urban studies, particularly in the urban and spatial analysis, remains marginal. The availability of a large amount of data, on the one hand, improves the accuracy and completeness of the measurements to capture phenomena that were previously difficult to investigate, but at the same time

increases the level of complexity in the approaches finalized to process and integrate this data (Einav & Levin, 2013) and presents severe pitfalls, such as the actual representativeness of the sample. The research activity aims to investigate under what conditions digital and mobile phone data can help to describe the daily mobility practices in Emilia Romagna Region. In addition to the description, the research should focus on the use of such data as planning and policy design tools, not limited to the ex-ante phase, but continuous along the entire policy cycle (design, assessment, monitoring, reassessment).

PhD candidates are invited to submit research proposals that articulate further the use of digital and mobile phone data to detect, interpret, and respond to complex mobility patterns in a city or network of cities across Emilia Romagna Region, eventually addressing specific target groups, transport means, economic sectors, etc.

Potential career opportunities at the end of the project will be research centres (Nomisma, CNR), transport companies (FS, FNM, ATM, TRENITALIA TPER), National and Regional Authorities.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Paola Pucci (PO) Paolo Beria (PA) Eugenio Morello (PA)

### Doctoral candidate's desirable skills and competences

The technical skills required from the candidate belong to different fields. On the one side, the candidate must be proficient in quantitative analysis. Instrumental skills in programming and/or statistical analysis are welcome. On the other, the candidate must have experience in the field of policy analysis and design, related in particular to mobility and land use planning.

### Description of the research group(s) in which the doctoral candidate will be integrated

The research group within the Department of Architecture and Urban Studies (DASU) carries out research, design experimentation and training activities in the field of urban mobility, accessibility measures, transport planning, economics and regulation with particular focus on the role of big and open data in supporting transport and mobility analysis, smart and sustainable mobility policy, access to housing and main services.

The research topics and the most relevant results can be found in the following publications:

- Lanza G., Pucci P., Carboni L. (2023). Measuring accessibility by proximity for an inclusive city in Cities 143,
- Concilio G., Pucci P., Raes L., Mareels G, (eds) (2021) The Data Shake. Opportunities and obstacles for urban policy making, Springer, ISBN 978-3-030-63693-7

- Pucci, P. (2021). Spatial dimensions of electric mobility. Scenarios for efficient and fair diffusion of electric vehicles. *Cities*, 110 - Shtele E., Beria P.; Lunkar V. (2022). Using location based social media data to explain COVID-19 spread in Italy, in *European journal of transport and infrastructure research* n. 22.
- Beria P., Lunkar V. (2021). Presence and mobility of the population during the first wave of Covid-19 outbreak and lockdown in Italy, *SUSTAINABLE CITIES AND SOCIETY* n. 65
- Pucci P. (2022), Mobile phone data: challenges for spatial research, in *Tema Special Issue 2/2022*, pp. 91-98
- Manfredini F., Pucci P., Tagliolato P., (2014), Toward a systemic usage of manifold cell phone network data for urban analysis and planning, in *Journal of Urban Technologies*, n.21(2) pp. 39-59.
- Pucci P., Manfredini F., Tagliolato P. (2015), Mapping urban practices through mobile phone data, *PoliMI SpringerBriefs Series*, ISBN 9783319148328
- Ryghaug M., Pucci P. et al. (2023) A Social Sciences and Humanities research agenda for transport and mobility in Europe: key themes and 100 research questions, *Transport Reviews*,
- Pucci P., Vecchio G., Bocchimuzzi L., Lanza G. (2019) Inequalities in job-related accessibility: testing an evaluative approach and its policy relevance. *Applied Geography*, 107, pp. 1-11
- The PhD programme in Urban Planning, Design and Policy (UPDP) is strongly connected with two main research structures dedicated to transport and mobility analysis, smart and sustainable mobility planning:
  - TRASPOL - Research Centre on Transport Policy (<http://www.traspol.polimi.it/en/>) is involved in research, teaching and consultancy in the transport and infrastructure sector, with particular regard to the relationship between public planning, economics and regulation. At the urban scale, TRASPOL works on public transport planning through the preparation of Sustainable Urban Mobility Plans and their economic evaluation, as well as through interfacing with transport models. In the field of long-haul passenger transport (rail, air and coach markets) TRASPOL works on regulation (unbundling, tenders), strategic studies and planning (services planning, restructuring, cost cutting).
  - CTC – Cycling & Cycling Territories Laboratory (<http://www.progetto.vento.polimi.it/>) is involved in research, training and consultancy in the field of development models related to "slowness", through cycling, slow mobility, and walking. The main project is the design and implementation of a cycling path along river Po from Venice to Turin is included in a protocol signed by MIT and MIBACT and the four regions crossed by the cycling path. In addition, two instrumental laboratories are equipped with specific facilities for analysis and simulation:
    - Laboratory of Urban Simulation, which provides support with creating physical models for simulation of energy consumption and environmental impact; <https://www.dastu.polimi.it/labsimurb-laboratorio-di-simulazione-urbana-fausto-curti/>
    - Mapping and Urban Data Lab (maud\_lab), which

provides support in the acquisition and processing of digital data and mapping;  
<https://www.maudlab.polimi.it/persone/>.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

In the PhD candidates' room, workstations are available for shared use, connected with a printer. All PhD candidates can use their own laptop with a wireless connection. Workstations and other equipment are available in the various laboratories linked with the doctoral programme.

In addition, access to the Laboratory of Urban Simulation and Data Analysis and Mapping provides additional support for the PhD research.

A relevant fruitful space for research, advanced training and projects is the CRAFT \_ Competence Center for Antifragile Territories, which is aimed at providing together with public institutions and the main stakeholders, skills necessary to face current urban transformations and future challenges. CRAFT can provide support for dealing with stakeholders and addressing the research toward the definition of analytical tools for designing urban policy. It is an integral part of the Department of Architecture and Urban Studies, and is funded as part of the MUR project "Department of Excellence 2023-2027" (<https://www.mur.gov.it/it/aree-tematiche/universita/programming-and-financing/departments-of-excellence>).

## Collaboration networks involving the research team

The collaboration networks supporting the PhD research activities take advantage from the research networks provided by Dastu as member of AESoP (Association of the European Schools of Planning, chaired in the past by Prof. Alessandro Balducci), AISRE (Italian Association of Regional Sciences), EURA (European Urban Research Association), INU (National Institute of Urban Planning) and SIU (Italian Society of Urban Planners). It also collaborates intensively with Planum the European Journal of Planning. In addition, many research projects funded by major European programs (e.g. H2020, Erasmus+, LIFE, Interreg, etc.) involve the research team as described in section 17.

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- EX-TRA – EXperimenting with city streets to TRAnsform urban mobility (Programma ERA-NET Cofund Urban Accessibility and Connectivity; 2021-2024). PI University of Amsterdam, Project partner Responsabile scientifico per il DASTU: prof.ssa Paola Pucci \_ <https://www.ex-tra-project.eu/>;

- COMMON\_ACCESS - COMMONing ACCESSibility in urban outskirts and beyond (Programma JPI DUT – Driving Urban Transition; 2024-2026). PI PI University of London Westminster, Project partner Responsabile scientifico per il DASTU: prof.ssa Paola Pucci.
- Raise Ub project\_ RAllways stations multi-SERVICE hUB (EIT\_UM).-Project: Multi-Modal Optimisation of Road-space in Europe' (MORE); Funding: Horizon 2020 (2022); PI Paola Pucci (DASTU)
- POLIVISU \_ Policy Development based on Advanced Geospatial Data Analytics and Visualisation Funding: Horizon 2020 – PI Project Partner (Grazia Concilio and Paola Pucci, DASTU) <https://www.polivisu.eu/>
- CLIMABOROUGH – Building Green and Climate Neutral City-Hubs (2023-2026). Responsabile scientifico per il DASTU: prof.ssa Grazia Concilio \_ <https://climaborough.eu/>;
- PALIMPSEST – CREATIVE DRIVERS FOR SUSTAINABLE LIVING HERITAGE LANDSCAPES (2023-2026). PI DASTU-Politecnico di Milano; responsabile scientifico del progetto: prof.ssa Grazia Concilio \_ <https://www.palimpsest-project.eu/>;
- MOBI-TWIN – Twin transition and changing patterns of spatial mobility: a regional approach (2023-2026). Responsabile scientifico per il DASTU: prof. Emmanuel Matsaganis \_ <https://mobi-twin-project.eu>
- Prin- 2022EJRHK7 - RECAP – Reducing car dependency through tailored policies to improve accessibility by proximity in highly car dependent territories (ongoing) – PI DASTU POLitecnmico di Milano (Paola Pucci)
- EU\_Doctorate General Research Center Collaborative Doctoral Partnership (CDP) – Smart, connected and clean mobility, retained amongst the highest ranked applications in Collaborative Doctoral Partnership with the JRC. (January 2021). PI DASTU Politecnico di Milano (Paola Pucci)

## Doctoral Position

### Edge Artificial Intelligence for underwater habitats characterization

## Doctoral Programme

### Risk Management

## Description of the doctoral position's main topic

Assessing the health status of underwater habitats is complicated by the inherent difficulties in deploying measuring equipment in such environments. Advances in robotic technologies, however, offer the opportunity to reduce the use of divers for surveying and to deploy the most advanced sensory tools where needed. In particular, the FutureData4EU project will use a drone, 'Blucy', characterized by a modular architecture and reconfigurable in its hardware and software equipment. This vehicle will act as a data collection platform through the sensors installed on board: flow cytometers, multibeam SONAR, high-resolution cameras, and physical parameter meters. However, the amount of data collected far exceeds the data transfer bandwidth typically available on drones, since only acoustic communications can be realized in the submarine environment. For this reason, developing methodologies for real-time processing of the collected data that can be implemented on board the drone (edge computing) becomes essential.

In particular, the PhD student will study machine learning and onboard artificial intelligence techniques aimed at enabling taxonomic characterization from optoacoustic images. Performing this processing onboard a drone will allow for consistent data compression. Furthermore, in flow cytometry, holographic diffraction patterns will be reconstructed in real-time through deep learning-based image reconstruction methods to continuously monitor the ocean microbiome, including plankton composition.

This activity requires intensive development work also at HW level. Indeed, electronic systems used in aquatic environments have specific requirements due to the difficult operating conditions. Firstly, an underwater system must be waterproofed for electrical isolation. In deep-water measurements, where the drone is subjected to high hydrostatic pressures, the most common approach is to house the electronics in thick-walled, heavy-weight metal containers. The processing instruments must therefore be miniaturised to reduce the size of their container in parallel. Minimizing power consumption is another important requirement to increase battery life.

Power and size constraints may imply limited computing and memory capacities, often differing by orders of magnitude from those of normal servers. However, the tasks required to process the acquired data, for autonomous navigation and mapping are undoubtedly complex. For this reason, the project will develop an integrated computing platform based on an integrated GPU architecture, specifically designed to be compact, low-power, and low-cost.

The ultimate goal is to implement an efficient HW/SW tool for biodiversity data collection and historisation, point analysis, time trend extraction, and anomaly detection. This will improve the approach to monitoring climate change adaptation and, consequently, the prevention of related risks and resilience, from an ecosystem perspective.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Luca De Marchi; Paolo Castaldi, Marco Di Felice; Mauro Mangia, Marco Dubbini

### Doctoral candidate's desirable skills and competences

Candidates for the fellowship must have basic skills in Signal Processing, Electronics, and Sensor technologies. Skills related to machine learning and data analytics, as well as Robotics and power management, are also considered useful.

### Description of the research group(s) in which the doctoral candidate will be integrated

The Research group of the EIT4SEMM Doctoral Programme includes the multidisciplinary specialisations needed to supervise the project activities. In particular, Prof. De Marchi is a lecturer in Electronics and was the scientific responsible for the Interreg projects SUSHI DROP and TECHERA through which the Blucy drone that will be used in the project was realized. Professors Marco Di Felice and Mauro Mangia are experts in artificial intelligence algorithms and advanced big-data management and signal processing techniques. Prof. Paolo Castaldi is a lecturer in Automation and will supervise the development of adaptive algorithms for autonomous driving, navigation and submarine vehicle control. Prof. Marco Dubbini is a lecturer in Topography and Geomatics and will supervise the development of SLAM (simultaneous navigation & mapping) tools. The PhD student will also interact with lecturers from the CIRI FRAME laboratory (Professors Cariani, Costantini, Ponti) on biological aspects. Further information can be found: 1) on the webpage of the SUSHI DROP project: <https://site.unibo.it/sushidrop/it> 2) on the webpage of the EIT4SEMM Doctoral Programme: <https://phd.unibo.it/eit4semm/en>.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The PhD student will have access to the Laboratories of the University of Bologna Advanced Research Center on Electronic Systems (ARCES). Such laboratories offer tools to design and test sensors and transducers for the measurement of physical quantities in several frequency ranges (displacement, inclination, temperature, acceleration, strain, etc.) and to configure and deploy wired and wireless sensor networks. They also offer facilities for computer vision, data analytics, data-driven model design and verification. Such computing tools will be used for training the neural networks used in drone data processing.

The Blucy drone itself, which packs instrumentation with a commercial value of more than €200,000, will be the main infrastructure available for the doctoral work.

## Collaboration networks involving the research team

The activities of the MSCA-COFUND project will be synergic with European initiatives such as the 'European Digital Twin Ocean' project carried out within the framework of the Horizon Europe mission 'Restore our Ocean and Waters' and regional initiatives such as the PR ERDF project StreamER (01/2024-06/2026), which aims to develop new sensory instruments for the Blucy drone. Finally, the collected data will be made available through the public database (<https://site.unibo.it/sushidrop/it/data>) created for the SUSHI DROP project.

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

Project "StreamER: Sensors, Robotic Technologies and Metagenomics for marine environment monitoring in Emilia Romagna, Funding scheme: "PR FESR Laboratori 2023" Emilia-Romagna region; Start date: 2/2024. Duration: 30 months. Principal Investigator Mirko Falavigna (T3 lab); Research Team members involved: Luca De Marchi (local coordinator), Mauro Mangia, Paolo Castaldi -Task leaders.

Project "Sustainable fisheries with Drones data Processing – SUSHI DROP", Funding scheme: Interreg CBC Italy-Croatia framework: Environment and Cultural Heritage, 1/1/2019- 31/12/2021. Principal Investigator: Luca De Marchi. Other Research Team members involved: Paolo Castaldi - WP leader.

Project "TECH.ERA - A new technology era in the Adriatic Sea – Big data sharing and analytics for a circular sea economy". Funding scheme: Interreg CBC Italy-Croatia framework. (1/4/2022-30/6/2023). Principal Investigator: Luca De Marchi.



Project “Energy ECS - Smart and secure energy solutions for future mobility”. (Funding scheme: H2020 ECSEL JU program), Starting date: 1/6/2021; Project Coordinator: Ksenia Avetisova; Research Team members involved: Luca De Marchi, Paolo Castaldi - Task leaders.

Project “Arrowhead Tools for Engineering of Digitalisation Solutions”. (H2020 ECSEL JU program), Starting date: 1/5/2019; Project Coordinator: Jerker Delsing; Research Team members involved: Marco Di Felice (local coordinator), Luca De Marchi- Task leader.

## Doctoral Position

### **Big data for Water-Food-Energy-Sustainable Agriculture Nexus**

## Doctoral Programme

Agricultural, Environmental and Food Sciences and Technology

## Description of the doctoral position's general/main topic

The “Water-Food-Energy-Sustainable Agriculture” Nexus is at the centre of the challenges arising from global population growth, climate change and natural resources depletion. In this context, the priorities identified for the agri-food sector are reduction of greenhouse gas emissions caused by human activities, saving of water resources, sustainable and circular management and use of natural resources, food and nutrition security, and innovative government models enabling sustainability and resilience. This approach is fully consistent with the objectives of the United Nations 2030 Agenda, but it is also aligned with the strategies of Horizon Europe and the Smart Specialization Strategy of the Emilia-Romagna Region. In this context, the adoption of digital technologies and advanced data management in the agri-food sector offer new tools to improve agricultural practices, processing strategies and food quality and safety in order to achieve the objectives of a sustainable transition of current production models.

This project will be hosted by the Department of Agricultural and Food Sciences (DISTAL) (about 160 faculty), covering a wide set of topics related to the agricultural and food sciences, natural resources management and the bioeconomy. Moreover, DISTAL hosts the “Inter-Department Centre of Food Industrial Research” (CIRI-Agroalimentare) devoted to the technology transfer to food industry. As part of DISTAL's highly integrated activities on the “Water-Food-Energy-Sustainable Agriculture Nexus”, this doctoral research must be shaped within at least one of the following objectives: i) ensure widespread use of "big data" technological platforms in the agriculture, forestry and food industry sectors; ii) promote the transition towards more efficient, environmental friendly and profitable food production systems; iii) allow companies to achieve production objectives even in case of unexpected events as frequently happens in agri-food production which is intrinsically dependent on natural factors and highly variable market demand; iv) consolidate and expand applications for the ICT industry in the agri-food sector. At the end of the three-year project, it is expected to train a professional figure who has gained the necessary skills for the development and transfer of digital and advanced data management technologies in the agri-food sector. The main career opportunities refer to research and development in the agri-food sector, environmental management, business management, consultancy for the public and private sectors and research management for international organizations.

## Sub-themes of the doctoral position's main topic (if any)

None

## Potential Supervisors

The supervisor team will be appointed among DISTAL faculty according to the profile of the selected candidate and main project's topic. Non-exhaustive list of possible supervisors: Diana Di Gioia, Michele Mattetti, and Silvio Salvi.

## Doctoral candidate's desirable skills and competences

### Required Skills

- A minimum of English language proficiency (IELTS overall minimum score of 6.5).
- Enthusiasm for visual analytics and data science
- Dynamic personality with passion for innovation and problem-solving
- A good understanding of experimentally derived biological, environmental, and engineering data, data types and appropriate analytical methods, fundamental statistical concepts including multivariate analysis
- Ability to work in multi-functional teams
- Proficiency in both written and verbal communication skills
- Desirable skills
- Thorough understanding and hands-on experience with the standard R/Python/Matlab data science stack, including libraries used for data cleaning and visualization.
- Ability to manage and contribute to projects autonomously
- Experience in the analysis of imaging data, time-histories, mass spec and proteomics data, shotgun sequencing, microbial communities and their functionality or statistical analysis of complex datasets.

## Description of the research group(s) in which the doctoral candidate will be integrated

The doctoral research groups at DISTAL form an (inter-)disciplinary group of fellow doctoral candidates and supervising professors. Thematically, the doctoral research groups are clustered according to their expertise to one of the nine research topics of the PhD course. Many professors regularly name doctoral topics or research areas in which they supervise doctoral theses. It is also possible to contact them directly via the personal pages which can be accessed via the following link: <https://distal.unibo.it/en/department/people/faculty>. A full list of DISTAL's research laboratories is also available by visiting the DISTAL's website: <https://distal.unibo.it/en/research/research-laboratories>. A more detailed description of selected research groups is here reported. Research group led by Diana Di Gioia The Laboratory of Agri-Environmental Microbiology is specialized in: identification of microorganisms and their characterization with both phenotypic and genotypic approaches; Microbial ecology of the soil, plant, and

insect environments; Functional analysis of the microbial community through RNAseq, shotgun DNA sequencing and phenotypic characterization of microbial isolates; The Application of feed additives such as beneficial microorganisms in agriculture, and the molecular characterization of microbial communities, utilizing a wide range of instruments for both classical and molecular analysis. Reference websites: i) <https://distal.unibo.it/en/research/research-laboratories/agro-environmental-microbiology-laboratory>; ii) <https://www.unibo.it/sitoweb/diana.digioia/en> Research group led by Michele Mattetti. The group is focused on outlining energy employed in crop productions in real-world farming conditions through CANBUS technologies; thus, through data coming from fleet of ag. machines to estimate the resources employed for crop productions. The group has extensive skills on massive field data collection and their analysis also through machine learning approaches. Reference websites: i) <https://www.linkedin.com/in/michele-mattetti-ab053831/>; ii) DATABUS project: <https://www.linkedin.com/company/data-bus/>. Research group led by Silvio Salvi. The research group operates in the area of crop molecular genetics and genomics, aiming at the identification and analysis of plant genes and functions involved in biotic and abiotic stress tolerance and plant development, in relation to genetic improvement for more sustainable cropping systems. The research group activities exploit bioinformatic knowledge and tools. Reference websites: <https://distal.unibo.it/en/research/research-areas/agricultural-chemistry-pedology-and-agricultural-genetics>

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

DISTAL has two main locations, one in Bologna and one in Cesena, but research activities are also carried out in Ozzano, Cadriano and Imola. Overall research facilities include fully equipped laboratories in agricultural chemistry, pedology, agricultural genetics (plant and animal), agricultural and food economics, agricultural engineering, agro-environmental and food microbiology, animal sciences, chemistry, biochemistry, botany, food science and technology, fruit tree and woody plant sciences, plant pathology and entomology. A full list of DISTAL's research laboratories is available by visiting the following webpage: <https://distal.unibo.it/en/research/research-laboratories>

A more detailed description of existing facilities of the aforementioned selected research group is here reported.

Research group led by Diana Di Gioia

The laboratory of agri-environmental microbiology possesses new equipment for microbial ecology surveys, such as growth chambers, bio-reactors for the growth of microorganisms, modern microscopes, renewed molecular biology equipment such as PCR thermocyclers, real-time PCR (Quant-Studio5), Next Generation Sequencing tools (NGS), and the basic equipment for proteomics. For phenotypic characterization, the lab has recently acquired the BIOLOG Cell Phenotyping apparatus and the TECAN SPARK enzymatic activity

reader. Moreover, for metabolite-related studies, the lab has recently acquired an LC-Triple quadrupole apparatus (LC-DAD-QQQ). The laboratory is also equipped with bioinformatic tools such as a high-performance computational unit for the analysis of high throughput data.

Research group led by Michele Mattetti

DISTAL has a large experimental farm (owning more than 500 ha), ag. machines and a large number of data acquisition systems compliant with Agricultural 4.0 technologies permitting easily to collect a large amount of data. Indeed, DISTAL has been monitoring fleet of ag. machines since 2019 and also is working on developing a database on CANBUS data.

Research group led by Silvio Salvi

The Plant genetics coordinates a fully equipped laboratory of molecular genetics and genomics, with real time PCR, DNA and RNA preparation, cell culture and transformation, several growth chambers and greenhouse spaces dedicated to plant growth and phenotyping experiment. The same lab manages a rhizotron facility dedicated to root phenotyping.

## Collaboration networks involving the research team

DISTAL faculty are active in numerous initiatives and platforms to address and define research priorities at a European level, including the transnational PRIMA program (Partnership for Research and Innovation in the Mediterranean Area which provides a strong focus on Nexus issues) as representative of the Italian Universities in the national Program committee designated by the CRUI and third party in the CSA 4PRIMA, EERA-Bioenergy, SETIS, EIP-WATER, EIP-AGRI, FOODINNOVA and others. DISTAL's faculties also represent the University of Bologna in the working groups of the CLAN and SPRING National Clusters.

In the private sector, DISTAL is active in the development of synergies that can allow the knowledge transfer to industry, also directing research towards industrial priorities and market demands. In this regard, DISTAL faculties are involved in the competitive calls for Axis 1 Research and Innovation financed by the POR-FESR through their participation in CIRI Agroalimentare and CIRI Energy and Environment, born within the project "High Technology Network" of the Emilia-Romagna Region. Furthermore, DISTAL faculties actively participated in the establishment of the National Agrifood Technological Cluster (CLAN) and in the implementation of two of the three research projects currently underway (SOFIA and PROSIT). The CLAN is a network of public and private bodies that collaborates with the MIUR in the implementation of the "National Smart Specialization Strategy" for the strengthening of the public-private partnership and is included in the Industry 4.0 strategy.

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

At EU level, the largest source of funding comes from the Framework Programmes. As part of the H2020 and HEU programs, DISTAL has so far received funding for 96 projects of which 11 coordinated. DISTAL is heavily involved in the CSA FIT4FOOD2030, a strategic project in the European agri-food sector which aims to implement the EU Food2030 Strategy and has an ERC Advanced Grant (LEAPS) project, 6 Marie Skłodowska Curie Action and 8 Erasmus+.

The large portfolio of competitive projects will therefore allow the doctoral student to collaborate and build relationships with high-profile EU researchers in different sectors related to agri-food. In particular, the PhD student will be able to interact with networks of researchers active on projects linked to the main pillars of the Nexus.

The list of international, national and regional projects of the aforementioned selected research group is here reported.

#### Research group led by Diana Di Gioia

- IMPLICIT - PRIN 2022 - Prof. Diana Di Gioia is responsible for the UNIBO Unit. The project aims at investigating the role of the *Helianthus annuus*' rhizosphere in the emission of VOCs during flowering, in the attraction of pollinators and finally in the sunflower oil properties. Daniele Alberoni is involved in the field experiments and laboratory analysis, Loredana Baffoni in data analysis
- SWEET3 – MASAF-OCM miele 2024 - PI Prof. Diana Di Gioia. The SWEET3 project aims to identify which botanical essences can support the nutritional needs of honeybees and simultaneously best support their immune system. Moreover, the project wants to investigate the potential of nectarous essences to improve the soil from a nutritional and microbial point of view, and the enhancement of nectar flow deriving from an improved soil microbiome. Daniele Alberoni (RTDa) is involved in the field experiments, laboratory, and data analysis. Research group led by Michele Mattetti
- DATABUS, PRIN 2020 call, Michele Mattetti, Principal Investigator
- GREEN SEED, PRIN 2017 call, Michele Mattetti, leader of a research unit
- New technical and operative solutions for the use of drones in Agriculture 4.0, Valda Rondelli, leader of a research unit

#### Research group led by Silvio Salvi

- WISH-ROOTS - Tuning the wheat root microbiome to improve soil health and optimize rhizosphere nitrogen cycling and availability. EJP European Joint Program - Soil, 3 years, 2022-2025. <https://www.wishroots-ejpsoil.net/>. Coordinated by Prof Tony Miller, John Innes Centre UK. Responsible of Research Unit UNIBO: Silvio Salvi. Role: investigating the genetic basis of wheat cultivars affecting root microbiome interactions.
- DROMAMED - Capitalization of Mediterranean maize germplasm for improving stress tolerance. EU PRIMA, Section 2 Call 2020 - Multi-topic. 3 years (2020 – 2023). Coord. P. Revilla CSIC Spain.

Responsible of Research Unit UNIBO: Elisabetta Frascaroli. Role: exploring the genetic variation of maize mediterranean landraces linked with drought and heat tolerance.

## Doctoral Position

### **Animal Biodiversity Big Data Integration**

## Doctoral Programme

Earth, Life and Environmental Sciences

## Description of the doctoral position's general/main topic

The project entitled ABiDal will improve the distribution estimates of protected animal species listed under the Habitats Directive, as well as those of invasive species of concern throughout Europe. This goal will be achieved by integrating big data from major Citizen Science's (CS) online biodiversity platforms (e.g., iNaturalist, GBIF) with standardized monitoring data collected by EU countries. The project therefore links regional (i.e. regions have jurisdiction on wildlife), national, and international commitments of the EU.

The project has two primary objectives. The first is to improve the conservation status of animal species by establishing conservation best practices that are formulated after integration of big data. The second is to serve as a roadmap for future integration of CS and standardized monitoring data into conservation policies and actions in general, thus leading to improved conservation of animal species under EU's Habitats Directive.

The methodology to achieve these aims will likely involve four main steps (these will be revised and adapted by the PhD candidate):

1. **Data Collection:** The PhD candidate will collect big data on animal species in the Habitats Directive from the main CS platforms (e.g., iNaturalist, GBIF). This data will include species occurrences, locations, dates, and potentially photos;
2. **Data Integration:** Next, she/he will integrate this big data with monitoring data of animal species. This integration will be facilitated through the use of algorithms and tools designed for data harmonization;
3. **Big Data Analysis:** Following the integration, she/he will identify patterns of distribution, population trends, and species richness. This analysis will be carried out using spatio-temporal Bayesian statistical models implemented in R using the INLA (Integrated Nested Laplace Approximations) package. The analysis will include a validation process to ensure the accuracy and reliability of the results. In this step, the PhD candidate will also account for detection probability and spatial autocorrelation with already established statistical approaches (i.e., site-occupancy models, N-mixture models, and Stochastic partial differential equations);



4. Guideline Development: Finally, based on the results obtained, the PhD candidate will develop guidelines to inform and improve conservation strategies. These strategies may include identifying priority areas or hotspots for conservation, evaluating the effectiveness of existing conservation strategies, and planning management interventions.

Thus, the expected outcome and impact of this project is to provide robust estimates of the distribution and conservation status of animal species under EU's Habitats Directive, as well as identifying hotspots for conservation strategies. Furthermore, this project will establish robust statistical approaches to improve the reliability of CS data in big data science.

The PhD candidate will therefore be trained to work in academia, or in the professional fields of conservation biology. The growing success of institutes and consultancy companies, also using big data applied to conservation biology problems, demonstrates the marketability of these skills.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Pietro Milanese, Marco Musiani, Alessandro Chiarucci

### Doctoral candidate's desirable skills and competences

Necessary: R programming and modelling, Cluster computer managing / programming, scientific writing, web page developing, independent working / self-organizing, social media managing.

Useful but not mandatory: big data management, climate / land-use change scenarios, GIS programming, Julia programming, Python programming, Citizen Science data analysis.

### Description of the research group(s) in which the doctoral candidate will be integrated

The research group primary focus on the conservation of animal biodiversity, with target species including both native and alien insects, mammals, and birds of European concern. Specifically, the main research topics investigated by this multidisciplinary group encompass and integrate a wide range of disciplines such as Citizen Science, Conservation Biology, Ecology, Ethology, Evolution, Invasive Species, Landscape Ecology/Connectivity, Landscape Genetics/Genomics, Species Distribution Models (SDMs), Spatial Statistics, and Zoology. The group aims to improve distribution estimates of animal species in the Habitats Directive and alien species through the integration of big data available on the main Citizen Science online biodiversity platforms with those of standardized monitoring protocols, collected by EU Countries. The expected impact of these project would lead to improved conservation of animal species under the Habitats Directive and serve as a roadmap for integrating Citizen Science and standardized monitoring data into conservation policies and actions. Thus, the research group span its interests also in vast geographical areas, including the

whole of Europe and North America, while looking also at the local scale in Italy. These projects are managed in collaboration with colleagues from European, North American, and Italian universities and research institutes, emphasizing a global approach to understanding and preserving animal biodiversity. Recent scientific papers, in which the member of the research group used big data sources and methodological approaches, has been published on Nature Communications, regarding continental distribution of all breeding bird species in Europe. These results are currently in use to refine patterns of distribution, population trends, and species richness as well as tools to develop guidelines to improve conservation strategies. Metrics: Dr. Pietro Milanesi (Associated Investigator, male; Scopus: publications = 43, 1018 citations, h-index = 21); Prof. Dr. Marco Musiani (Associated Investigator, male; Scopus: publications = 80, 4805 citations, h-index = 35). He has been a Professor at the University of Calgary, Canada during 2005-2022. He was awarded >\$1,445,000 (CDN) in funding as PI in the past 6 years (and an approximately equal amount as co-PI), a period during which he (co)supervised 26 Highly Qualified Personnel (HQP), including graduate students and postdoctoral fellows. For more details have a look at the following links: <https://www.unibo.it/sitoweb/pietro.milanesi>; <https://www.unibo.it/sitoweb/marco.musiani>.

### Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

Wifi access, work station (desk, sit, computer screen, audio system) in the office of the Supervisor (Pietro Milanesi), MS Team access, two computer work stations (i.e., servers for big data management & analyses), meeting room for 12 persons (with wifi access).

### Collaboration networks involving the research team

Conservation Genetics Area (BIO-CGE) - ISPRA (Italy), WWF Italia (Italy), Department of Biological Sciences - University of Calgary (Canada), EBCC - European Bird Census Council (Switzerland), Large carnivores Department - Norwegian Institute for Nature Research (NINA) (Norway), Unit Biodiversity and Conservation Biology - Swiss Federal Institute for Forest, Snow and Landscape Research, WSL (Switzerland), Wildlife Ecology and Management Department - University of Freiburg (Germany), Dipartimento di Biologia Ambientale - Università di Roma 'La Sapienza'(Italy).

### International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

Big data used for similar purposes in research project in Canada:

- Project code 10029069 - A portable DNA testing device, PI: Marco Musiani (Full Professor), Budget 220440 €;

- Project code 10031755 - Conservation genomics of Briti, PI: Marco Musiani (Full Professor), Budget 50000 €;
- Project code 10028786 - Human impacts on isolation, PI: Marco Musiani (Full Professor), Budget 104280 €;

Big data available for similar purposes (comparisons) in research project in Italy:

- Project code CN\_00000033 – NextGenerationEU, under the National Recovery and Resilience Plan (NRRP), Project title “National Biodiversity Future Center -NBFC”, SPOKE 4 - ACTIVITY 4, PI: Alessandro Chiarucci (Full Professor), co-PI: Marco Musiani (Full Professor) & Pietro Milanesi (Researcher), Budget 56000 €.

## Doctoral Position

### **Environmental effects on calcification and accumulation of pollutants in marine calcifiers**

## Doctoral Programme

Innovative Technologies and Sustainable Use of Mediterranean Sea Fishery and Biological Resources

## Description of the doctoral position's general/main topic

The concurrent action of ongoing climate change and accumulation of anthropogenic-related pollutants is a major threat for coastal marine environments. In this context, effects on marine calcifiers are particularly relevant as they provide habitats for a wide variety of associated species, thus supporting marine biodiversity and providing ecosystem services.

This doctoral project aims to identify the main environmental drivers affecting growth and calcification processes in marine calcifying organisms, and to search for patterns of bioaccumulation of organic pollutants in their skeletal structures, under a global change scenario. Target species will be selected across different taxonomic groups, including key species of commercial interest collected along the coast of the Adriatic Sea (Italy).

Different oceanographic databases will be utilized to obtain a thorough characterization of the physical, chemical, and biological environment at the sampling sites. The health status of the study organisms will be assessed by means of multiple integrated approaches, including molecular, physiological, (bio)chemical and morphological analyses of the organic tissues and skeletal structures. Possible interaction between environmental drivers, skeletal properties, calcification rate and overall physiological performance will be investigated by means of field and laboratory-based experiments. Cutting-edge genome-wide sequencing approaches will be employed to identify genes involved in relevant metabolic pathways to be used as diagnostic tools. Levels of accumulation of organic pollutants will be examined among the study species, and within species, in different organismal compartments. Recent studies have demonstrated that e.g., PAHs can accumulate in the skeleton of different calcifying organisms, likely due to their hydrophobicity and interaction with skeletal lipids.

In a second phase of the project, the obtained experimental data will provide the basis for modelling studies. Modelling approaches will be implemented: i) to produce simulations of dispersal/transport and transformation of pollutants across the study area; ii) to produce simulations of dispersal and transformation of pollutants under a global change scenario; iii) to produce hazard and vulnerability maps for the specific

pollutants, based on obtained molecular and biochemical data for the study species. The project could be the basis for the further assessments of the long-term sequestration of organic pollutants in the whole Mediterranean Sea, given the widespread distribution of the target species. In a context of ongoing climate change, the project is particularly relevant, as future climate conditions will lead to increasing ocean acidification and subsequent dissolution of skeletal structures in calcifying organisms, with a potential release of accumulated chemical pollutants in coastal waters and increasing detrimental effects on marine biodiversity.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Mauro Marini – Research Director, IRBIM-CNR. Jaap Kaandorp – Associate Professor, University of Amsterdam. Alessandra Spagnolo – Researcher, IRBIM-CNR. Miriam Ruocco – Researcher, University of Bologna.

### Doctoral candidate's desirable skills and competences

The PhD candidate is expected to possess a good knowledge of marine biology and ecology, marine ecosystems processes and anthropogenic impacts in coastal areas (e.g., bioaccumulation of pollutants in marine organisms). Knowledge of one (or more) of these fields: biology and ecology of marine calcifying organisms, basics of oceanography, analytical chemistry, molecular ecology, would be beneficial but it is not mandatory before the start of the project. Experience in scientific diving, scientific missions and collection of environmental data would also be deemed useful. Technical skills: knowledge of main methods for the estimation of skeletal properties and calcification rate in marine calcifiers, HPLC analysis, or basic molecular biology techniques, would be highly appreciated. Knowledge of modelling approaches to produce simulations of dispersal of pollutants in water systems would be considered a plus.

### Description of the research group(s) in which the doctoral candidate will be integrated

The PhD student will be integrated in different research units with diverse and complementary expertise: the Institute of Marine Biological Resources and Biotechnologies of National Research Council (IRBIM-CNR), the Computational Biology Group of the University of Amsterdam (UVA), and the Department of Biological, Geological, and Environmental Sciences (BiGeA) - University of Bologna (UniBO). The branch of the CNR Institute for Biological Resources and Marine Biotechnologies (IRBIM-CNR) (<https://www.irbim.cnr.it/en/>) carries out research activity in the central Mediterranean region and in the Adriatic Sea focusing on management of coastal areas, ecosystem modelling, chemical processing in soil, groundwater and sea water

of organic and inorganic compounds and pollutants, biogeochemical mechanism in the water column and in the water sediment interface, oceanography, and assessment of impacts induced on the marine environment by anthropogenic activities. The Group of Computational Biology of the University of Amsterdam (UVA) is part of the Computational Science Lab of the Faculty of Science (<https://staff.fnwi.uva.nl/j.a.kaandorp/index.html>). The research group is specialized in modelling morphogenesis of basal organisms (scleractinian corals and sponges) at different levels of organisation (genes-cells-biomineralization-organismal level-influence physical environment). The group does research on biomineralization (experimental and modelling work), on growth and form of corals and the influence of light and hydrodynamics on the morphological plasticity and calcification in corals. The BiGeA-UniBO (<https://bigea.unibo.it/en/index.html>) hosts various research groups with diverse expertise on calcification ecology, animal physiology, molecular biology and ecology, genome evolution and environmental stressor effects that can support the doctoral project. Furthermore, the UniBO Department of Chemistry “Giacomo Ciamician” (<https://chemistry.unibo.it/en/index.html>) hosts the Biocrystallography and Biomineralization Group (BiocryBiomin), with extensive experience on biomineralization studies in calcifying organisms that could be involved in the project.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The PhD student will take advantage of existing facilities of the various institutes involved: IRBIM-CNR, University of Amsterdam (UVA), Fano Marine Center (FMC), BiGeA-UniBO.

The CNR-IRBIM runs some oceanographic facilities (<https://www.irbim.cnr.it/en/mare-in-tempo-reale/>) for the study of marine ecosystems and of the environment (e.g., “Acqua Alta” oceanographic platform; <https://www.ismar.cnr.it/infrastrutture/infrastrutture-oceanografiche/piattaforma-acqua-alta/>), and can provide access to long-term oceanographic observation databases for the Adriatic Sea (1911-today).

The general focus of the Computational Science Lab (CSL) at UVA is on modelling Dynamical Complex Systems from nature. It is expected that optimization techniques for inferring parameters in complex dynamical systems, cell-based models as developed in several national and international projects, are very relevant for the project. CSL has access to high computing facilities (GPU computing, cluster computing), machine learning expertise and Scientific Visualization facilities.

The doctoral candidate will also be supported by the research infrastructure of the Fano Marine Center (FMC), the Inter-Institute Center for Research on Marine Biodiversity, Resources and Biotechnologies, a joint research center among University of Bologna, University of Urbino, Marche Polytechnic University, Anton Dohrn Zoological Station, National Research Council (<https://fanomarinecenter.eu/it>). The FMC has 3,000 square meters of equipped laboratories and it hosts multidisciplinary, integrated, cooperative research for the study of marine biodiversity, resources, and biotechnologies. At FMC, diverse research equipments and

facilities are available, as fluorescence microscopy, atomic force microscopy, FT-IR microscopy, UHPLC, an oceanographic buoy, basic molecular biology instruments. BiGeA-UniBO can provide scientific diving equipment, underwater photo/video systems, systems of controlled aquaria, advanced electron microscopy systems (SEM, TEM), a fully equipped molecular biology lab. The Department of Chemistry “Giacomo Ciamician” (UniBO) can provide X-ray diffractometers, scanning electron, probe/spectroscopic microscopes, Raman imaging, and a fully equipped crystallization lab.

## Collaboration networks involving the research team

The PhD student will be supported by a network of national and international collaborators that can provide additional expertise and/or experimental facilities/equipments:

1. MARCHE POLYTECHNIC UNIVERSITY/FMC: The research group led by Prof. Anna Annibaldi is focused on the determination of organic and inorganic pollutants in different environmental matrices (seawater, sediments, marine organisms).
2. BAR-ILAN UNIVERSITY: the Group of Algal and Coral Photobiology and Ecophysiology, led by Prof. Zvy Dubinsky is a research group specialized in coral ecophysiology, algal photobiology and biotechnology, marine ecology, gene regulation, biological clocks, and energetics of photosynthesis.
3. THE HEBREW UNIVERSITY OF JERUSALEM: the Group of Oceanography, marine and aquatic biogeochemistry, led by Prof. Jonathan Erez, is a research group specialized in biomineralization, marine aspects of the global carbon cycle, particularly photosynthesis and calcification in view of ocean acidification, biogeochemistry of stable carbon isotopes in marine and aquatic systems.

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

ENDRIMUS-PRIN 2022-PNRR (ENVIRONMENTAL DRIVERS AFFECTING FATTENING AND CALCIFICATION PROCESS OF WILD AND FARMED MUSSELS IN THE ADRIATIC SEA). PRIN – RESEARCH PROJECTS OF NATIONAL RELEVANCE, FUNDING GRANTED BY THE ITALIAN MINISTRY OF EDUCATION, UNIVERSITY AND RESEARCH (MIUR). Stefano Goffredo: PI - UniBO; Alessandra Spagnolo - IRBIM-CNR, Antonella Penna - University of Urbino: Co-PIs.

FNRS grant (FONDS DE LA RECHERCHE SCIENTIFIQUE - BELGIUM). A computational study of the effects of environmental stress on coral calcification using a spatio-temporal model. Jaap Kaandorp: Co-PI - University of Amsterdam; Jean-Francois Flot: PI - Université Libre Bruxelles.

## Doctoral Position

**Advancing AGRicultural research through OMICS science: development of advanced metabolomics and proteomics approaches for the characterization of crop plant matrices**

## Doctoral Programme

Chemical Sciences

### Description of the doctoral position's main topic

The PhD project focuses on omics sciences, which encompass high-throughput technologies designed to identify or track alterations occurring at the genetic or metabolic level within an organism. These technologies typically utilize sophisticated mass spectrometric methods and/or nuclear magnetic resonance, generating an extensive amount of data.

Omics sciences have initially been applied to clinical research to understand the complex biological processes underlying the development of diseases and to discover novel biomarkers. Their role is pivotal in personalized medicine and early diagnosis approaches. Due to their great potential and continuous advancements at the instrumental and bioinformatic levels, omics sciences are now being applied to various other scientific fields. One such field is agricultural research, where they are expected to play a transformative role in the coming years. The application of these disciplines to plant matrices offers numerous opportunities in terms of new applications and advancements in knowledge. Moreover, it provides a means to address critical issues that have not seen significant improvements thus far. The large-scale collection of omics data enables a systems biology approach to understand plants from the individual cell to the mature plant, not only during development but, more importantly, in response to changing environmental conditions.

For example, omics sciences can provide a deeper understanding of the impact of climate change on plants, enabling the development of innovative molecular breeding approaches to enhance crop production. Furthermore, omics sciences can help unravel the evolution of herbicide and insecticide resistance, which is crucial for designing more effective pesticides and tailored crop protection strategies. Other applications include improving biofuels production based on renewable resources such as plants, algae, and waste materials from agro-based activities, as well as generally enhancing circular economy approaches in this field.

This topic is of high interest and relevance not only at the regional level, where Emilia-Romagna is one of the Italian regions with the most developed and prosperous agri-food systems, but also at the national level, since agriculture is one of the country's main key economic sectors.



Given that the application of omics science to agricultural research is a rapidly emerging field, it is essential to train dedicated professionals who can lead the transition from traditional methods to omics-assisted approaches. The focus of this PhD project is to equip the candidate with knowledge about tools and strategies in separation science applied to agricultural samples, using state-of-the-art chromatographic equipment coupled with high-resolution mass spectrometry (HRMS). Specifically, the project will employ untargeted metabolomics and proteomics to collect the largest amount of data from samples, which will be further evaluated using bioinformatic approaches.

### Sub-themes of the research project/topic (if any)

None

### Potential Supervisors

Alberto Cavazzini, Martina Catani, Flavio Antonio Franchina

### Doctoral candidate's desirable skills and competences

The preferred candidate should possess a degree in Chemical Sciences or a related discipline. A keen interest in analytical chemistry is essential, while prior exposure to omics science or chromatographic methods (e.g., through a Master's internship) is advantageous but not obligatory. Additionally, the candidate should demonstrate a robust inclination towards collaboration and teamwork, along with the flexibility to engage in research stints overseas.

### Description of the research group(s) in which the doctoral candidate will be integrated

The PhD candidate will be part of a dynamic research group consisting of young, internationally recognized researchers working in the fields of separation science and food chemistry. The team possesses a combination of theoretical knowledge and practical expertise in each step of analytical workflows, from sample preparation to data evaluation. The research group's activities cover a wide range of samples, including (bio)pharmaceuticals and petrochemicals as well as complex mixtures derived from food or plants. The group employs various chromatographic approaches, from targeted to untargeted methods, and utilizes advanced analytical techniques such as multidimensional GC or LC. Moreover, the research group is one of the few worldwide to apply multicolumn approaches in preparative LC conditions, using advanced platforms that enable the internal recycling of samples and solvents. This results in an intensified process compared to single column processes and a significant reduction in solvent consumption. The group uses the array of instrumental platforms in a multi-disciplinary approach to gather a wealth of information on phytochemicals, physiological and molecular parameters related to the monitoring of food quality, determination of bioactive molecules and characterisation of crop plant matrices for the agri-food supply chain. This is possible through the use of advanced multivariate statistical methods such as Permutational MANOVA, Canonical Analysis of Principal ordinates and Weighted Correlation Network Analysis that aid the identification of correlations

between individual and/or subset of “omics” traits in relation to the specific scientific and applicative challenge under research. Ultimately addressing objectives such as: providing the agri-food industry with diagnostic markers for the evaluation of product quality; providing the industry operators with decision supporting tools in critical points of the food supply chain from raw genetic/metabolic selection to agricultural conditions to adopt to improve food quality; and optimising preparative and processing green-based-techniques.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The doctoral candidate will have access to recently renowned laboratories equipped with state-of-the-art chromatographic instruments and software.

### LC equipment available:

- Omics platform composed by micro and nano UHPLC coupled to HRMS (Orbitrap)
- 2D-LC coupled to Q-TOF-MS
- HPLC-MS/MS (triple quadrupole)
- Many HPLC/UHPLC with Diode Array Detection
- Single column preparative LC
- Multicolumn countercurrent preparative LC platform

### GC equipment available:

- Multi tools Extraction and Enrichment platforms in combination with many GC (and GCxGC) systems coupled to MS, FID, and TCD detectors

### Software:

- Untargeted LC-HRMS software for metabolomics (Compound Discoverer), proteomics (Proteome Discoverer) and lipidomics (Lipid Search)
- Data analysis and chemometrics platforms for aligning and comparing chromatographic data in automated workflow (ChromaTOF, ChromeCompare+, MassHunter).

A High-Resolution NMR equipment is also available in the Department.

## Collaboration networks involving the research team

The research team has a strong network of national and international collaborations with leading groups in separation science. Some of these experts specialize in the fundamental aspects of chromatography, such as Professor Gert Desmet (VUB Brussels, Belgium) and Professor Attila Felinger (University of Pécs, Hungary). Others focus on more practical aspects of chromatography, including its application to omics science for clinical purposes, such as Professor Gunda Köllensperger (University of Vienna, Austria) and the

characterization of food and plant matrices, such as Professor Aldo Laganà (University of Rome, Italy), Professor Luigi Mondello (University of Messina, Italy), Professors Hilary Rogers and Carsten Muller (Cardiff University, UK), Professor Leonardo Bruno (University of Calabria, Italy), Professor Antonio Ferrante (University of Milan, Italy). In this context, it is worth mentioning that Professor Alberto Cavazzini has taken on also the role of Scientific Director of the (national) Council for Agricultural Research and Economics (CREA) as of September 2023.

The research group also has strong connections with pharmaceutical industries, such as Fresenius Kabi iPSUM (Villadose, Rovigo, Italy), and Merck (Darmstadt, Germany), as well as multinational companies producing chromatographic equipment and/or columns, such as Chromacon/YMC (Zurich, Switzerland), Knauer (Berlin, Germany), Agilent Technologies (Santa Clara, CA, USA), Waters (Milford, MA, USA), Chiral Technologies (Illkirch, France), Mac-Mod Analytical (Chadds Ford, PA, USA), Markes international (Bridgend, Wales, UK) and Sepsolve Analytical (Pererborough, England, UK).

The research group also has strong connections with petrochemical industries involved in the development of new energies and materials, such as TotalEnergies (Paris, France) and LyondellBasell (Houston, USA).

**International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year**

The research team is presently engaged in the following projects aligned with scientific endeavours that correspond to the PhD proposal:

- PRIN 2022 PNRR “Design of high-profit fostered bioactive compounds through integral valorization of seaweeds infesting the Mediterranean sea (DreamWEEDme)”, PI: Prof. Anna Laura Capriotti. Prof. Alberto Cavazzini is responsible for the UniFE unit. Duration: 2 years.
- Fondo per la Crescita Sostenibile “I-FISH - Sistema Intelligente di Produzione, distribuzione e tracciabilità di alimenti funzionali a base di pesce”, Responsible for the project: VRM s.r.l. Prof. Alberto Cavazzini is responsible for the UniFE unit. Duration: 3 years.
- PNRR, Mission 04, Component 2, Investment 1.5 “Ecosystem for Sustainable Transition In Emilia-Romagna - ECOSISTER”. Responsible for the project: UNIBO. Prof. Alberto Cavazzini is responsible for the activities of the UniFE unit in WP1 and Prof. Luisa Pasti in WP5. Duration: 3 years.
- PNRR, Mission 4, Component 2, Investment 3.1 “EMBRC-UP”, PI: Prof. Roberto Danovaro (Stazione Zoologica Anton Dohrn). Prof. Alberto Cavazzini and Martina Catani are responsible for UniFE activities in WP5. Duration: 3 years.
- Piano Operativo Nazionale 2014 – 2020, Azione IV.6 - Contratti di ricerca su tematiche Green. “Valorizzazione di biomasse, incluse quelle di scarto, attraverso lo sviluppo di processi sostenibili per il recupero di molecole ad alto valore aggiunto per l’industria nutraceutica e per la produzione di

biocarburante ed agroenergia”. PI Prof. Luisa Pasti, Dr Damiana Natasha Spadafora is responsible for the research. Duration 3 years.

- PRIN 2022 “Unique analytical workflow involving COMPLEMENTARY TECHNIQUES for the reliable molecular identification of hydrocarbons (CompleTe)”, PI: Prof. Flavio A. Franchina. Duration: 2 years.
- PNRR, Investment 1.4, “National Centre for HPC, Big Data and Quantum Computing”, HPC Spoke 8. PI: Prof. Stefano Volinia. Duration: 3 years.
- PR FESR 2021-2027 “Produzione di ingredienti ad alto valore aggiunto dai sotto-prodotti della filiera della frutta attraverso un approccio di bio-raffineria a cascata (FRUREFINERY)”, Responsible of the project: SITEIA.PARMA (in the person of Prof. Augusta Caligiani, University of Parma). Prof. Martina Catani is the responsible of the UniFE unit represented by Tecnopolo di Ferrara.
- POR FESR 2021-2027 “ODOR-GC - Rilevazione di composti ODORIGENI e molestie olfattive tramite GasCromatografo portatile e compatto”, Responsible of the project: PROAMBIENTE SCrl. Prof. Flavio A. Franchina is the responsible of the UniFE unit represented by Tecnopolo di Ferrara.

Increasing productivity, sustainability and ecoefficiency in organic farming by using microorganisms to promote plant growth and control plant pathogens (symbiotic agriculture).

## Doctoral Position

**Increasing productivity, sustainability and ecoefficiency in organic farming by using microorganisms to promote plant growth and control plant pathogens (symbiotic agriculture)**

## Doctoral Programme

Management and conservation of the soil microbiota for sustainable and eco-efficient production

## Description of the doctoral position's general/main topic

Increasing productivity, sustainability and eco-efficiency in organic farming is possible by using microorganisms able to promote plant growth and control plant pathogens. To develop innovative microbial-based pesticides and implement protocols for their application in cropping systems, both their efficiency and their environmental safety should be tackled. Particularly, the environmental fate of beneficial microbial communities in the agri-environment and their impact on the population structure and biodiversity of natural microbiota should be assessed. Finally, the use of new 'omics' technologies to monitor the soil-plant system will be important for the generation of large datasets, and the resulting multilayer information will be possibly implemented in AI algorithms for early recognition of plant diseases, abiotic and nutritional stresses.

Therefore, we propose following research goals:

- Development and implementation of protocols and procedures for the safe use and distribution of microbial biocontrol agents in cropping systems
- Development of specific equations describing the dynamics of microbial communities introduced and/or present in agricultural environments
- Development of numerical algorithms able to represent and organize large sets of biological data for the description, efficacy, and safety of microbial inputs into and along the agri-food value chains.

The project will be part of the EU COST Action 22158 MiCropBiomes (<https://microcbiomes.eu/>) and the doctoral student will have the chance to participate into the COST Action activities, share results and attend workshops targeted to elucidate the microbe-microbe and plant-microbe interactions in the agro-environment. Additionally, the project will be connected to the OneHealth COST Action coordinated by UNIMORE in the section: "Environmental sustainability and health of agri-food productions" with the scope to assess the dietary quality of food from plants (fruits and vegetables) grown according to the principles of symbiotic agriculture. The proposed research will also be connected with ongoing actions related to climate

resilient agriculture, soil preservation, agroecology that are carried out in the frame of the Ecosystem for Sustainable Transition in Emilia-Romagna (Project ECOSISTER, PNRR.4.2.15)

Given the increasing request of consumers of nutritious and healthy food, produced according the most advanced and innovative systems that preserve the quality and safety of the agri-environment, the industry and the major global retailer increasingly require specialists who are able to plan and manage such agri-food production chains, especially in pre-harvest. Therefore, career opportunities on the regional, national, and international levels are open and will be more and more available in the near future.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Emilio Stefani, Enrico Francia, Davide Giovanardi

### Doctoral candidate's desirable skills and competences

The prospective candidate is a recent graduate in any subject related to Plant Pathology and Disease Control, Agronomy, Microbiology and Microbial Genetics, Molecular Biology. He/she has a deep knowledge of Molecular Plant Pathology and Plant-Microbe Interactions. He/she possesses technical skills to conduct his/her research in both Plant Pathology and Crop Production labs (isolation and characterisation of bacteria and fungi; isolation, purification, and amplification of nucleic acids; metagenomics; population genetics). Knowledge of computerised image analysis and bioinformatics would be greatly appreciated. Soft skills will complement the prospective candidates, as the ability to interact with others, work in a multicultural and multinational team, willingness to actively participate to seminars, workshops, conferences, ability to plan his/her work agenda and prioritize experiments and deliver results at the planned time; ability to supervise graduate students and technical staff.

### Description of the research group(s) in which the doctoral candidate will be integrated

The Plant Pathology group has a long experience in diagnostics of plant pathogens and in the development and implementation of innovative pest control methods based on the discovery, characterisation and use of microbial biocontrol agents. Additionally, the group is involved in research projects aiming at studying the plant-associated microbes through a metagenomic approach; microbial communities and their interaction with crop plants are studied, aiming at the discovery of novel microbial biocontrol agents. Several beneficial microbes are available in the lab collection, some of them are now used to develop novel biopesticides in industrial partnerships. Finally, plant-microbe interactions are studied at the molecular level to understand the key signals that stimulate the innate plant resistance to pathogens. The Crop Production group has a long experience in the agronomic and genomic factors for sustainable and quality intensification of

production, in ecophysiological and molecular aspects of adaptation of crops to environmental stresses. Among the most relevant results are: i) the identification of genes/QTLs involved in low temperature stress, flowering time and development in cereals; ii) the use of biostimulants for the qualitative and quantitative improvement of production in Solanaceae; iii) the valorization of digestate from biogas plants for the production of innovative fertilizers; iv) the morpho-physiological and molecular aspects of the interaction between crops and useful soil microorganisms (AMF e PGPB).

### Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

Access to the laboratory of Plant Pathology and to the laboratory of Crop Production, fully equipped with basic and advanced equipment (sterile hoods, centrifuges, phytotrones, climatic chambers, autoclaves, DNA analysers, thermocyclers, and qRT-PCR machines). Access to the Biogest-Siteia centre (HPLC, Gas Chromatography and GC-Mass Spectrometry). Access to the CIGS centre (NMR, Spectrometry, Electronic microscopy (TEM, SEM, Confocal), Proteomics, Image analysers, Bioinformatic tools).

### Collaboration networks involving the research team

- EU COST Action 22158 "MiCropBiomes". <https://micropbiomes.eu/>
- EU COST Action 21111 "OneHealthdrugs" <https://onehealthdrugs.com/structure/management-committee/the-team/>
- Deutsche Phytomedizinische Gesellschaft, Braunschweig, Germany. <https://phytomedizin.org/de/home>
- UNIGREEN, The Green European University Alliance. <https://unigreen-alliance.eu/>
- Regione Emilia Romagna High Technology Network. <https://www.retealtatecnologia.it/>
- BarleyNet, The Barley Genome Network. <https://www.inetbio.org/barleynet/about.php>

### International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- LIFE21-ENV-IT-LIFE-MICROFIGHTER/101074218 "Innovative Zeo-Biopesticides, based on useful microorganisms, for eliminating the use of copper-based pesticides". <https://webgate.ec.europa.eu/life/publicWebsite/project/LIFE21-ENV-IT-LIFE-MICROFIGHTER-101074218/innovative-zeobiopesticides-based-on-useful-microorganisms-for-eliminating-the-use-of-copper-based-pesticides>. Emilio Stefani, PI; Davide Giovanardi, co-PI.
- European Commission, EUPHRESKO network. Strategic Research Agenda Objective 2017-R-5.2: Inventory and validation of quality control procedures for the extraction of nucleic acids for real-time PCR used for the diagnosis of pests.

- CCS-Aosta and Regione Valle d'Aosta: Characterisation of plant endophytes, their application in symbiotic agriculture, and their use in the production of functional food.
- Project AmaPero: Innovative approaches to control the brown rot of pear. RiNova Soc. Coop. and Emilia Romagna Region.
- Project IoHOP: Quality valorisation of the Italian hop based on a multi-approach strategy. MIUR, PRIN, call 2022, code 2022M3HR45.
- Project CLIMAVIP: Integrated agro-genomic approaches for resilience and environmental sustainability in grapevines and tomato (Emilia-Romagna Region PG/2023/307259).
- Project UNIHEMP: Use of industrial hemp biomass for energy production and new biochemicals (MIUR, Azione PNR 2015-2020 Chimica Verde, ARS01\_00668).



## Doctoral Position

### Smart Analysis of Agricultural IoT Data

## Doctoral Programme

Information Technologies

### Description of the doctoral position's main topic

Agriculture is facing economic challenges in terms of productivity, climate and environmental changes, cost efficiency and relative reduction in labor availability due partially to depopulation of rural areas. Precision agriculture will increase farm productivity, reduce the demand for manual labor for complicated tasks, and help to make farm management more sustainable. The Emilia-Romagna region is one of Italy's most advanced regions in terms of agricultural production and sensitivity to innovation.

The goal of the SAngrIoT project is to develop a framework for efficient data collection and analysis in smart agriculture applications. Specifically, SAngrIoT aims to reach the following objectives.

- Design and implementation of a multi-technology IoT flexible data collection platform.
- Development of a multi-level processing framework that can efficiently combine “dew computing” (at IoT sensing nodes), “edge computing” (at IoT gateways), and “cloud computing” (at cloud servers).
- Design and implementation of advanced data analysis algorithms.
- Design and actuation of an extensive experimental validation campaign.

The SAngrIoT project will leverage relevant connections (already existing owing to previous/on-going collaborations) aimed at maximizing the impact of the research activities.

At regional level, there will be interactions with the municipality of Parma, Emilia-Romagna region and companies (e.g., E.S.T.E. s.r.l. and OpenFields s.r.l.). The technological transfer will also be fostered through the spin-off of the University of Parma things2i s.r.l. (<https://www.things2i.com/>).

At national level, there will be interactions with relevant institutional entities (e.g., Ministero dell'agricoltura, della sovranità alimentare e delle foreste, MASAF; Agenzia Spaziale Italiana, ASI) and major companies (e.g., STMicroelectronics, Leonardo).

At international level, there will be interactions with leading academic and industrial entities. In particular, the following two entities will act as Associated Partners within the SAngrIoT project: Universidad Politécnica de Madrid (UPM) (<https://www.upm.es/>), the oldest and largest Spanish technical university and a top-

quality academic establishment, and TECNALIA RESEARCH & INNOVATION (<https://www.tecnalia.com/en/>), an independent, non-profit applied research center of international excellence.

The SAngrIoT project will pave the way to career opportunities in the context of smart agriculture, where data analysts will play a more and more relevant role in the next future.

### Sub-themes of the doctoral position's main topic (if any)

The main sub-themes of the research project are associated with the objectives outlined at the previous point.

- Design and implementation of a multi-technology IoT flexible data collection platform: this is instrumental to integrate, in principle, any information flow generated by an IoT sensing node.
- Development of a multi-level processing framework that can efficiently combine “dew computing” (at IoT sensing nodes), “edge computing” (at IoT gateways), and “cloud computing” (at cloud servers): the design of this framework is expedient to optimize the trade-off between processing and communication costs over the entire system.
- Design and implementation of advanced data analysis algorithms: intelligent data analysis strategies (e.g., embedded Artificial Intelligence, AI, techniques) with heterogeneous time horizons will be designed and implemented, in order to extract key information associated with the monitored cultivation.
- Design and actuation of an extensive experimental validation campaign: at least two relevant use cases will be considered through appropriate collaborations, currently being defined, with farms.

### Potential Supervisors

Gianluigi Ferrari, Luca Davoli, Laura Belli, Tommaso Ganino

### Doctoral candidate's desirable skills and competences

The candidate is expected:

- to have a background in electrical and computer engineering and/or computer science (or a comparable discipline), with a solid foundation on data analysis and practical experience with statistical software (such as Excel, SPSS, SAS) and mastery in data analysis languages including SQL and Python;
- to exhibit exceptional analytical abilities to compile, structure, examine, and present substantial data sets with precision and thoroughness;
- to be capable of critically evaluating data to derive meaningful, actionable insights;
- to demonstrate superior communication and presentation capabilities, adept at simplifying complex data insights for audiences without a technical background.

**Additional requirements include:**

- attitude at report writing and presenting findings;
- ability to work under pressure and meet tight deadlines;
- prior experience in data analysis or a related field.

**Description of the research group(s) in which the doctoral candidate will be integrated**

The University of Parma, UNIPR, (<https://www.unipr.it/>) is one of the oldest Italian universities, dating its origins to the 11-th century. It currently enrolls around 30000 students in 10 departments and a few interdepartmental research centers. UNIPR is in the 30 top performing universities in Italy in the major EU funding schemes FP7, H2020, HE, having received more than 90 grants so far. The SAngrIoT project will be carried out at the Information Engineering sub-area of the Department of Engineering and Architecture. The Information Engineering sub-unit is the main site of advanced research and graduate studies in Electronics, Computer Engineering, Telecommunications and related fields.

The research activities will be carried out at the Internet of Things (IoT) Lab (<https://iotlab.unipr.it/>), which focuses on advanced wireless networking, signal processing and data analysis, IoT and smart systems. Currently, the IoT Lab group includes a few faculty members, several PhD students and post-docs, together with several Master students. The IoT Lab has strong scientific ties with several international (from US, Europe, Asia) and national academic and industrial groups. The main research projects are funded by institutional bodies and private companies, both Italian and international. In these scenarios, the activities range from data collection to efficient communication/actuation and data analysis (including machine learning-based applications). Technological transfer from the IoT Lab is fostered also through things2i s.r.l. (<https://www.things2i.com/>), a spin-off company of the University of Parma dedicated to providing innovative activities in the areas of IoT and smart systems, with applications to the following scenarios: smart factory, smart home, smart agriculture, smart city, and smart health. The IoT Lab will interact, withing the SAngrIoT project, with the Crop and Plant Science (Cro.P.S.) research group (<https://crops.unipr.it/>) of the University of Parma. The research of the group is focused on the biology, physiology, propagation, genetic improvement and characterization of tree and shrub species of agricultural interest, the conservation and enhancement of biodiversity, the design and sustainable management of crop systems for fruit production and biomass. The training skills of the sector concern the general principles of arboriculture, the propagation, the biology and physiology of tree plants and their products, even in post-harvest, the evaluation of the quality of fruits and the resulting products, agrobiotechnologies of the different fruit species. The support of the Cro.P.S. research group will be instrumental to the design and implementation of meaningful data analysis algorithms by the IoT Lab.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The equipment of the IoT Lab of UNIPR is composed of more than 150 nodes including, among the others, Raspberry Pis, Variscite ARM System On Module and carriers (both custom and commercial such as Amber Carrier Boards), Texas-Instruments; Upboards; INTEL NUC; INTEL RealSense, wearable devices, Inertial measurement units (Shimmer, XSens, LPB2), U-blox localization boards (GNSS and RTK), Quorvo UWB anchors, RGB and thermal cameras, Zolertia Z1, Arduino nodes and Intel Galileo boards.

A large range of network connectivity are encompassed, including IEEE 802.15.4, IEEE 802.11, SubGHz (Diginet and LoRaWAN), Bluetooth Low-energy (BLE), 4G, 5G (FPGA-based) RFID and others.

The IoT devices have been integrated into different testbeds and projects.

The IoT Lab has also recently extended his equipment with smart agriculture-specific IoT commercial devices, such as indoor and outdoor LoRaWAN gateways (Milesight UG67, Milesight UG65, iC880A LoraWAN concentrator), LoRaWAN smart water meters (OY1310), smart water valves (MClimate, Aqua-scope), LoRaWAN solenoid valves controllers (Milesight UG50X and Milesight UG510X), soil water potential sensors (Decentlab DL-TRS21), LoRaWAN soil sensors (Milesight EM500-SMTC), water pressure sensors (Milesight EM500-PP) and environmental sensors (Milesight EM500-CO2), leaf temperature sensors (Implexx LT-1T), and several Xfarm-based sensors.

As the SAngrIoT project strongly relies on the use of an IoT-oriented communication infrastructure, the IoT Lab testbed will provide a perfect setting to carry out efficient implementations of the envisioned solutions.

UNIPR has also extensive knowledge in terms of numerical simulations, using both commercial software suites (Matlab, Mathematica, etc.) and network simulators (Opnet, NS-3, etc.), relying on the use of multiple programming languages (C, C++, Python, Java, etc.).

## Collaboration networks involving the research team

The SAngrIoT project will benefit from several national and international collaboration networks, built because of previous and on-going projects. We summarize a few relevant academic and industrial partners which will collaborate to the project.

STMicroelectronics (<https://www.st.com/>), Dr. Danilo Pau): constant and fruitful interactions related to the design and implementation of advanced AI algorithms for IoT nodes.

Universidad Politecnica De Madrid (<https://www.upm.es/>), Spain (Prof. José-Fernán Martínez-Ortega): UPM is one of the Associated Partners of the SAngrIoT project and the interactions with the ETSIST, GRyS research group will leverage a long-term collaboration from the AFarCloud project (<https://cordis.europa.eu/project/id/783221>).

Tecnalia Research & Innovation (<https://www.tecnalia.com/en/>), Spain (Dr. Jesus Maria Santamaria Yugueros): Tecnalia is one of the Associated Partners of the SAngrIoT project and the interactions with this center will leverage a long-term collaboration from the AFarCloud project.

CENTRIA University of Applied Sciences (<https://web.centria.fi/en>), Finland (Dr. Mikko Himanka):

Centria is an excellence research center in the context of smart agriculture and the interactions with this center will leverage a long-term collaboration from the AFarCloud project.

Prof. Ferrari is also a member of the Scientific Council of INSIDE Industry Association (<https://www.inside-association.eu/scientificcouncil>). INSIDE Industry Association is the European Technology Platform for research, design and innovation on Intelligent Digital Systems and their applications. The direct interactions with INSIDE will represent an invaluable opportunity for the applicant, who will be able to interact with the top European entities in the context of digital (agricultural) systems.

**International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year**

In the following, we summarize the main projects which the IoT Lab is involved in, indicating explicitly the duration of the projects (in months, M), together with the years of duration. For a more detailed list please refer to the IoT Lab dedicated web page (<https://iotlab.unipr.it/projects/>). In all summarized projects, the IoT Lab is active in the design and implementation of innovative IoT data collection systems and data analysis algorithms.

[2025-2027, 24 M] “Filiere Italiana Del Luppolo E Dell’orzo Per Il Settore Brassicolo” (FILO, Italian Hops And Barley Supply Chain For The Brass Industry), V Bando dei Programmi e dei progetti presentati nell’ambito dell’Avviso n. 0182458 del 22.04.2022. Sponsor: Ministero dell’agricoltura, della sovranità alimentare e delle foreste, MASAF. PI: Prof. Tommaso Ganino. Co-PI: Prof. Gianluigi Ferrari.

[2022-2025, 36 M] “Smart Models for Agro-food Local value chain based on Digital technologies for Enabling covid-19 Resilience and Sustainability” (SMALLDERS). Sponsor: European Commission. Call H2020-PRIMA-SECTION-2021-MULTI-TOPIC. PI: Prof. Giuseppe Vignali. Co-PI: Prof. Gianluigi Ferrari.

[2022-2025, 36 M] National Center for Agricultural Technologies (Agritech), National Restart and Resilience Plan (Piano Nazionale di Ripresa e Resilienza, PNRR), Spoke 3: “Enabling technologies and sustainable strategies for the smart management of agricultural systems and their environmental impact.” Sponsor: Ministero dell’Università e della Ricerca (MUR). PI: Prof. Tommaso Ganino. Co-PI (group leader for the activities related to IoT): Prof. Gianluigi Ferrari.

[2020-2022, 39 M] “Aggregate Farming in the Cloud” (AFarCloud). Sponsor: European Commission & Ministero dell'Istruzione, Università e Ricerca (MIUR, Italy), Call H2020-ECSEL-2017-2-RIA-two-stage. Project reference: 783221. Participants: 59, across 13 European partners. Coordinator: Universidad Politecnica De Madrid, Madrid, Spain. PI: Gianluigi Ferrari.

## Doctoral Position

### **Big data for mapping consumers' trends and boosting food sustainability and healthy food choices**

## Doctoral Programme

Food Science

## Description of the doctoral position's general/main topic

The adoption of healthy and sustainable diets, together with the transition to sustainable food production systems, is urgently needed to counteract the double burden of non-communicable diseases and climate change. Sustainable diets are defined by FAO as “those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources”.

In this context, identifying strategies to steer consumers' eating habits toward healthier and more sustainable eating choices is a crucial aspect, as food choices impact both human health and the environment. Several interventions have been tested to encourage desired food choices among consumers including, but not limiting to, the use of nudges to prompt healthy food consumption in canteens and retailing settings, both in real and hypothetical contexts (e.g., online surveys, eye-tracking methods, etc.). These interventions can be classified into cognitively-oriented interventions, aiming at influencing what consumers know, affectively-oriented interventions, which seek to influence how consumers feel, and behaviourally-oriented strategies, which strive to influence what consumers actually do.

These approaches require, on the one hand, the ability to develop interventions tailored to consumers' beliefs and behaviour. This implies, on the other hand, the need to create new databases for integrating nutritional, environmental, socio-economic and supply chain data and information. Innovative skills, including the capacity to develop new information technology tools (e.g. apps), for collecting and analysing data are therefore needed. This would facilitate the testing of statistical models, which supply chain operators (e.g., retailers, canteen managers, etc.) and public administrations can use to offer innovative and increasingly personalized services, based on the analysis of the current situation and the consumer needs.

This project will allow the formation of specialized and innovative skills in the agrifood system. In particular, the research will require the integration of multiple areas, including social sciences (e.g., consumer science,

behavioural economics), human nutrition, environmental science and supply chain management. From a practical perspective, the integration of the various actors involved in the agrifood system will be requested for implementing the effective sharing of information and data aimed at promoting, enhancing and disseminating healthy and sustainable food choices. Finally, the project will allow the dissemination of knowledge and skills and, therefore, the capacity for innovation in production and services to the individual and the community.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Davide Menozzi, Francesca Scazzina, Giovanni Sogari

### Doctoral candidate's desirable skills and competences

The candidate should have knowledge in food science, in particular related with the food systems sustainability and nutrition aspects (e.g., basic knowledge in human nutrition, food systems sustainability, etc.), including some basic knowledge in economics and consumer behaviour.

Statistical and econometric knowledge, including knowledge about the use of some statistical package such as SPSS or R, is considered useful but not mandatory before the project starts.

### Description of the research group(s) in which the doctoral candidate will be integrated

The University of Parma (UNIPR) is a State University, and is self-governing and has research, administrative, organisational, and accountancy autonomy. UNIPR boasts top-level scientific research from food and agriculture to biotechnologies, from innovative treatment to experimental medicine, not to mention law, economics and arts. The Agricultural Economics group at the Department of Food and Drug (University of Parma) is mostly involved in the study and research of the economic aspects of the sustainability of agri-food systems and the consumer behaviour of food and novel food. The research activities of the group focus on some macro-topics in the field of Agricultural and Food Economics and Marketing of food products. These are some of the activities that are implemented: the analysis of consumer behaviour of food products and novel foods, as well as the effect of intervention strategies (e.g. nudging), using qualitative (e.g. focus groups, in-depth direct interviews) and quantitative methodologies (e.g. theoretically based sample surveys, discrete choice experiments, eye-tracking methods, etc.); the study of the agri-food system and business organization, the analysis of the economic-financial performances of agricultural companies and food industries, etc. The Human Nutrition group at the Department of Food and Drug (University of Parma) is involved the evaluation of food consumption from a nutritional perspective, and in the promotion of healthy and sustainable diets. For the first topic, several activities are implemented, such as survey of consumption and eating habits



through food diaries, 24-hour recalls and consumption frequency questionnaires; nutritional and environmental evaluation of diets and consumption patterns; evaluation and validation of food consumption biomarkers; development of nutritional databases (fibres, phytochemical compounds and other compounds of nutritional interest). For the second topic, the group develops nutrition education programs for different population groups; nutritional coaching and nudging to promote healthy and sustainable food choices; development of ICT applications for edutainment, coaching and nutritional education. Moreover, it is already involved in food education projects implemented in primary schools of the Parma area.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The Agricultural Economics (AE) group created the LA.RI.SA Laboratory in 2015 (Food & Stakeholder Research Laboratory). The laboratory offers services to companies and institutions for the organization of Focus Groups, Stakeholder Engagement events, as well as research using different techniques, including choice-based conjoint analysis, eye-tracking techniques, etc. The group will provide access to this laboratory and to other software used for statistical analysis of consumers' choices and dataset (e.g., price series), such as NGENE and NLOGIT, allowing the estimation, simulation and analysis of choice data, MATLAB and GAMS. Eye-tracking technologies are also used, in particular hardware (Tobii Pro Fusion 250HZ, Complete hardware package with Tobii Pro Fusion 250HZ eye tracker <https://www.tobii.com/products/eye-trackers/screen-based/tobii-pro-fusion>), and software (Tobii Pro Lab Screen-Based One Edit <https://www.tobii.com/products/software/applications-and-developer-kits/tobii-pro-eye-tracker-manager>).

The Human Nutrition (HN) group disposes of web/mobile applications allowing the use of educational materials, the assessment of dietary and other lifestyle parameters through the registration of dietary records and questionnaires, and the planning and management of weekly diet of children. In addition, UNIPR is a member of the Scientific Committee of the GIOCAMPUS educational programs (<https://www.giocampus.it/it/giocampus-project/>), in charge of defining educational programs and of performing scientific studies within the GIOCAMPUS cohort.

## Collaboration networks involving the research team

The Agricultural Economics (AE) and the Human Nutrition (HN) groups are involved in several international projects.

The AE group collaborated in the past with PhD programmes at the University of Newcastle (UK), and at the Cornell University (USA).

The HN group collaborated with Ulster University (Northern Ireland, UK) and with the King's College, London (UK), as well as with other EU and US institutions (e.g., the University of California Los Angeles – UCLA, USA).

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

DG JRC tender on “Literature review on the efficiency of voluntary versus mandatory standards on consumers’ purchase choices of sustainable food” (Tender JRC/SVQ/2022/VLVP/0299, 2022-2023), Davide Menozzi (PI).

PROMEDLIFE (Novel food products for the PROMotion of MEDI-terranean LIFEstyle and healthy diet, PRIMA, 2022-ongoing), to increase adherence to the MD through a multi-actor approach, Francesca Scazzina (PI), Davide Menozzi (WP lead).

MED4Youth (Mediterranean Enriched Diet for tackling youth obesity, PRIMA, ref 2018-SECTION2-14), to demonstrate how an energy-restricted Mediterranean-style diet intervention is effective against youth obesity. Francesca Scazzina (PI, WP lead)

MSCA GF “CONSUME Health Using consumer science to improve healthy eating habits”. Partner organization: Cornell University (Ithaca, USA); Secondment: European Food Safety Authority (EFSA). <https://giovannisogari.com/consumehealth-msca-project/about-the-project.html>, Giovanni Sogari (PI)

STRENGTH2FOOD (Strengthening European Food Chain Sustainability by Quality and Procurement Policy, Horizon 2020, <https://www.strength2food.eu/>, 2016-2022), aims to understand consumers perception of food quality schemes (FQS), to evaluation of the sustainability of short food supply chains and FQS, and to assess the sustainability of school canteens menus. Davide Menozzi (Task lead), Francesca Scazzina (Task lead).

PRIMEFISH (Developing Innovative Market Orientated Prediction Toolbox to Strengthen the Economic Sustainability and Competitiveness of European Seafood on Local and Global markets, 2015-2019, GA 635761), a webtool was developed (PrimeFish DSS) for fishermen, producers and processors, public authorities and other stakeholders. Davide Menozzi (WP lead).

BALANCE, (Norwegian Aquaculture in the span between domestic social responsibility and international market demands, Research Council of Norway, 2019-2022), to analyse consumers’ perception of Norwegian salmon. Davide Menozzi (PI, WP lead).

## Doctoral Position

### **Mapping consumers' trends and boosting sustainable food choices**

## Doctoral Programme

Sistema Agro-Alimentare

## Description of the doctoral position's general/main topic

Topic: Monitoring of the eco-physiological response of crops to agrophotovoltaic conditions

General frame:

Agrophotovoltaics (APV), systems that combine agriculture and electricity conversion on the same land, are considered valuable solutions for the decarbonisation of the energy system in general and of the agro-industry sector in particular.

For a sustainable development of APV technologies research must be carried out to study how crop yield, crop quality and safety, water consumption, pest and disease occurrence are affected by shading under APV.

Monitoring systems need to be developed to aid crop management (i.e. precision agriculture) and to certify crop performance.

Experiments carried out under commercial APV systems and monitoring, mainly based on wireless systems, will provide large datasets that will be used to calibrate and validate a modelling platform, developed at UCSC, department of Sustainable Crop Production-DIPROVES), to optimise the design and the management of APV system.

The project contributes to acquire knowledge and to develop tools to manage the decarbonisation of the agro-industrial system. This will contribute to implement 4.0 technologies in agricultural systems.

The candidate will carry out research in the APV plant settled at UCSC. A collaboration with a regional project (AgrivoltER-Emilia Romagna region) and an international project (Value4FARM; Horizon 2020) will be established.

The expertise acquired by the candidate will open great job opportunities, thanks to the huge number of ongoing collaborations established between UCSC and energy and multiutility companies and to the multidisciplinary expertise and contact of the involved supervisors.

## Sub-themes of the doctoral position's main topic (if any)

None

## Potential Supervisors

Paola Battilani (Plant pathologist, head of DIPROVES), Stefano Amaducci (Agronomist, expert in APV), Daniele Trinchero (Electronic Engineer, iXem Labs responsible, expert in wireless communications and IoT for agriculture)

## Doctoral candidate's desirable skills and competences

Computer use skillness

Useful: Plant ecophysiology/crop physiology, programming languages, geostatistical data analysis, algorithms for agriculture data analyses

## Description of the research group(s) in which the doctoral candidate will be integrated

The Department of Sustainable Plant Production Sciences - DI.PRO.VE.S was established by unifying the former Institutes of: Agronomy, Genetics, and Herbaceous Crop Cultivation Fruit and Viticulture Entomology and Plant Pathology. DI.PRO.VE.S also includes: the "Research Center on Biodiversity and Ancient DNA" (BioDNA) the "Research Center for GeoSpatial Analysis and Remote Sensing" (CRAST). The Department is organized into three thematic research areas (or Sections), which are strongly characterized and integrated with each other: Agronomy and Plant Biotechnologies, Horticulture and Viticulture, Sustainable Protection of Plants and Food.

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

APV plant, access to laboratories, greenhouses, climate chambers, and fields with all facilities requested for agronomy, plant breeding, crop management and plant health studies, including remote sensing tools and remote data transmission and electronic/telecommunication laboratories for IoT device manufacturing or verification. Computing resources and software requested for data management and analysis.

## Collaboration networks involving the research team

The collaboration network includes all the staff members of DIPROVES-UCSC and DET-Politecnico di Torino as well as the national and international network of the whole staff. Many international research groups, located in all the continents, have long lasting collaboration with the involved departments and this will be part of the potential collaboration network of the PhD.

International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

EFSA-Mycotoxin mixtures in food and feed: holistic, innovative, flexible risk assessment modelling approach - MYCHIF (GP/EFSA/AFSCO/2016/01; 2017-2019) PI Paola Battilani.

Horizon Europe (HORIZON)-HORIZON-MSCA-2022-DN-01, Safe food in a world of changing climate: The doctoral training programme to develop novel control, mitigation and risk assessment methods for biotoxins BIOTOXDoc (Project: 101119901, 2023-2027) PI Franz Berthiller, BOKU, Paola Battilani UCSC PI

PNRR- Agritech-National Research Center Spoke 6 Management models to promote sustainability and resilience of agricultural production systems (2022-2025) Stefano Amaducci WP leader, Paola Battilani Task leader

POR FESR Emilia-Romagna Agro.Big.Data.Science project

POR FESR Emilia-Romagna AgrivoltER project

Horizon Europe Value4Farm

## Doctoral Position

### Smart Analysis of Agricultural IoT Data

## Doctoral Programme

Sistema Agro-Alimentare

### Description of the doctoral position's general/main topic

Heat stress poses a significant threat to animal welfare and dairy production efficiency, impacting the sustainability of the dairy sector across environmental, economic, and social dimensions. Commonly employed heat abatement systems such as shades, fans, and sprinklers incur high energy costs for farmers and exacerbate environmental concerns. Given the imperative of climate change, there's a pressing need for long-term, sustainable strategies, including enhancing the thermo-tolerance of animals themselves.

A systems biology approach is proposed to understand the intricate mechanisms underlying heat stress resilience in dairy cows. The hypothesis is the existence individual variability in resilience, suggesting genetic and/or epigenetic influences, as well as potential involvement of the microbiome. To address these questions, a comprehensive study will be conducted using Italian Holstein dairy cows at the Catholic University experimental farm CERZOO.

The research will span three years and involve four cohorts of cows, each monitored extensively for various parameters related to heat stress, including dry matter intake, milk yield and composition, methane emissions, and behavioral indicators. Biological samples such as blood, milk, feces, and rumen fluid will be collected regularly for analysis, encompassing metabolomic profiles and the microbiome composition. The bacterial community of fecal and ruminal samples will be collected and will be assessed by means of 16S rRNA gene amplicon sequencing analysis. Briefly, the DNA of target taxa will be amplified after extraction using primers targeting the bacterial 16S rDNA and PCR products will be sequenced with the Illumina technology. Data analysis will be performed using bioinformatic tools for taxonomic sequence assignment.

The interdisciplinary nature of systems biology will be leveraged, integrating various -omics datasets using bioinformatic tools. This holistic approach aims to unravel the biological basis of heat stress resilience, leading to the identification of novel biomarkers and sustainable mitigation strategies. Anticipated outcomes include reduced need for pharmacological treatments, improved product quality, decreased antibiotic use, enhanced consumer safety, and increased farmers' income. Moreover, improved production efficiency is expected to lower methane emissions per unit of production, contributing to climate change mitigation in dairy farming.

## Sub-themes of the doctoral position's main topic (if any)

None

## Potential Supervisors

Luigi Lucini, Vania Patrone, Luca Cattaneo

## Doctoral candidate's desirable skills and competences

Technical skills required from the candidate include:

- A good academic background related to microbiology;
- Strong knowledge of molecular and cellular biology principles, theories, and techniques;
- Proficiency in various laboratory techniques, such as DNA isolation and PCR;
- Ability to design and execute experiments, analyse data, and draw meaningful conclusions;
- Proficiency in using statistical analysis software and other relevant tools for data analysis.

Knowledge that can be deemed useful but not mandatory before the project starts includes the ability to assess data regarding next generation DNA sequencing.

## Description of the research group(s) in which the doctoral candidate will be integrated

The area of Agricultural, Food, and Environmental Microbiology focuses its research on the microbiological aspects of the entire agri-food chain, from agricultural soil and water to the recovery of agri-food processing residues, through the production of fermented foods and the microbial contamination of zootechnical and human foods. This research area particularly addresses the following themes: Physiological, biochemical, and molecular taxonomy of lactic acid bacteria Genetics and biotechnology of lactic acid bacteria Probiotics of lactic acid bacteria Study of the physiological and technological traits of lactic acid bacteria of interest in the preparation of fermented foods Dairy technology Food microbiology and biochemistry Meat microbiology Animal biotechnologies Fourth range vegetables Wine microbiology Antibiotic resistance of lactic acid bacteria used in food. There are five specific thematic categories of research: Food Microbiology, Agricultural Microbiology, Environmental Microbiology, Microbial Biotechnologies, and Microbial Ecology, of which the lines of work are detailed: Food Microbiology: Improvement of foods with traditional and innovative techniques Quality and microbiological safety of foods; pathogens and contaminants Fungi as contaminants in foods Agricultural Microbiology: Physiological, genetic, and technological study of bacteria and yeasts of interest in agri-food productions Bioenergy production Environmental Microbiology: Bioremediation with particular attention to the degradation of plastic materials Microbial Biotechnologies and Microbial Ecology: Intestinal microbial ecology Microbial ecology of natural and agri-food systems Microbial genomics and metagenomics Archaea in the food chain of animals and humans Mechanisms of

resistance to infectious diseases in domestic animals and biotechnologies aimed at their enhancement  
Antibiotic resistances in microorganisms of agri-food interest

### Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

- Metagenomic analysis of microbial consortia by high-throughput, MinION-based Oxford Nanopore Technologies sequencing.
- Real-time PCR/Digital Droplet PCR quantification of target microbial populations.
- Full-equipped laboratories for DNA and RNA extraction and manipulation.

### Collaboration networks involving the research team

Collaborations within the Department with the group of experts in metabolomics; within Institution with the Department of Animal Science, Food and Nutrition (DIANA), collaborations with the food industry and with International Universities

### International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- SCALA-MEDI (Horizon 2020 Prima – 2021-2024) “Improving sustainability and quality of Sheep and Chicken production by leveraging the Adaptation potential of Local breeds in the Mediterranean area”. Paolo Ajmone Marsan general coordinator
- SEBASTIEN Smarter livestock Breeding through Advanced Services Tailoring Innovative and multi-source data to users’ Needs (EU-CEF TELECOM CALLS 2020 CEF-TC-2020-2). Paolo Ajmone Marsan PI Università Cattolica
- PRIN (Projects of National Interest) 2023-2025. Epigenetic basis of adaptation to climate change: a comparison of indicine and taurine - EPI-ADAPT. Paolo Ajmone Marsan General coordinator
- LEO (2017-2023) “Livestock Environment Opendata - Piattaforma Opendata per la Zootecnia”. Paolo Ajmone Marsan PI Unicatt
- BENELAT. Regione Lombardia (2018-2020). Interventi a breve e lungo termine per il miglioramento del benessere, dell’efficienza e della qualità delle produzioni dei bovini da latte della Lombardia. Paolo Ajmone Marsan general coordinator



### Doctoral Position

#### **Mathematical Modelling for Medical Practice**

### Doctoral Programme

Mathematics

### Description of the doctoral position's main topic

Mathematical modelling plays a crucial role in advancing medical practice by providing quantitative frameworks to understand complex biological systems and disease processes. Through the integration of mathematical principles with biomedical data, such as clinical records, imaging studies, and molecular profiles, the project aims to design mathematically grounded predictive models that aid in diagnosis, treatment optimization, and patient care management. These models and the associated numerical simulations allow for the exploration of hypothetical scenarios and the prediction of outcomes, ultimately contributing to personalized and precision medicine approaches. The project lists four distinct research directions, with a common denominator given by a rigorous model formulation and the massive use of big data in the framework of biological processes, disease dynamics and medical practice

### Sub-themes of the doctoral position's main topic (if any)

#### *Mathematical models for neurodegenerative diseases*

This theme aims to develop advanced mathematical models to better understand the progression and underlying mechanisms of neurodegenerative diseases. Leveraging large-scale data sets including clinical records, neuroimaging data, and genomic profiles, we will construct mathematical models that integrate complex biological information. A numerical approach will be employed to identify the parameters of the models by using a huge number of medical data. The developed models will enable the simulation and prediction of disease progression, offering insights into the dynamics of neurodegeneration and aiding in the identification of potential therapeutic targets. The project will adopt a multidisciplinary approach to validate the models against clinical data and to translate findings into actionable insights for diagnosis and treatment strategies. Ultimately, this research aims to contribute towards advancing precision medicine approaches for neurodegenerative disorders, paving the way for personalized interventions and improved patient outcomes.

### *Mathematical models for imaging problems*

Mathematical approaches to imaging sciences are currently of two kinds: data-driven machine learning (ML) searches for hidden correlations among big data, and model-driven approaches, leverages physical models of how data is generated. The exciting frontier lies in integrating these two approaches. This involves physics-informed ML: exploiting physical models to guide the design and training of machine learning algorithms, and deep Learning with prior knowledge: Incorporating prior knowledge about the expected features or structures into deep learning architectures. The project aims at providing the candidate with the theoretical and applied mathematical skills for working in this cutting-edge field with an overview to applications which are vital to understand recent advances and current challenges in imaging science.

### *Mathematical models for structured datasets.*

Understanding the convergence, stability, and generalization capabilities of learning algorithms has become pivotal for advancing the field of machine learning and the development of the so-called artificial intelligence technologies. Within this context, the project will study the dynamics of learning non-convex landscapes within neural networks, with a particular focus on large structured datasets. The primary objective is to incorporate genuinely geometric features into available simple so-called “mean-field” models, to enhance the understanding of how neural networks hierarchically recognize and process geometric patterns within data, laying the foundation for the development of more robust and versatile models. The study will also leverage large datasets of real medical images, thus contributing to the development of automated diagnostic software with improved accuracy and efficiency.

### *Mathematical Models for Biomedical Pattern Formation*

The temporal evolution of ensembles made of microscopic entities in mutual interaction is of crucial importance and cross-disciplinary interest (in biology, ecology, physics, chemistry). Microscopic interactions can eventually lead to macroscopically organized patterns, called Turing patterns. The potential applications in medicine are diverse and promising. Understanding the mathematical principles underlying Turing pattern formation is essential for elucidating the mechanisms of self-organization and pattern generation in nature, such as biological anomaly formations. Numerical computations and large-scale simulations are fundamental to help understand how patterns emerge and are regulated, while capturing diverse pattern structures, and may lead to new therapeutic approaches.

## Potential Supervisors

Germana Landi; Serena Morigi; Gabriele Sicuro; Valeria Simoncini; Maria Carla Tesi

## Doctoral candidate’s desirable skills and competences

### ***Scientific and technical skills***

Background in mathematical modelling, numerical computations and computational data analysis, that can be acquired during an undergraduate and graduate degree in mathematical sciences and related fields.

### Description of the research group(s) in which the doctoral candidate will be integrated

The proposal involves the participation of several professors from the Department of Mathematics, including three members of the Faculty Board of the PhD course in Mathematics. The sub-themes topics perfectly integrate with the PIs activities. Over the years the PIs have significantly contributed to the proposed subjects, and have collaborations and scientific publications on the proposed topics, also through conferences and summer and winter schools. Some of the founding topics are thoroughly presented in classes within the Mathematics Master program, for which the PIs also have large teaching experience.

- CIME-EMS Summer School: Exploiting Hidden Structure in Matrix Computations. Algorithms and Applications, June 21-26, 2015, ref. V. Simoncini
- Int.I Ph.D. Summer School: Mathematics and Machine Learning for Image Analysis, June 4-12 2024, ref. S. Morigi, at DiMAT, Bologna
- “Youth in High-Dimensions: Recent Progress in Machine Learning, High-Dimensional Statistics and Inference”, 29/05-02/06/23, SISSA
- “Sketching, Mixed Precision, and Associated Algorithms for Scientific Computing”, 18 -19 January 2024, dr. D. Palitta, at DiMAT, Bologna

### Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The Department of Mathematics provides very high quality resources consisting of expertise, knowledge and advanced laboratories. In particular, the Laboratory for High Performance Graphics and Vision Computing, equipped with 3D printer, High Performance workstations, as well as Virtual and Augmented Reality devices.

### Collaboration networks involving the research team

Principal investigators are actively involved in interdisciplinary collaborations, specifically in medicine and computational data analysis (Physics Dept, CINECA, profit companies and other international Universities). Such a consolidated scientific environment, active in interdisciplinary broad collaborations, is an ideal setting for international students.

### International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

*National projects*

- AlmaIdea2022. “Modellazione matematica della malattia di Alzheimer: approcci numerici, analitici e con neuroimmagini”, local PI: G. Landi
- PRIN2022, “Low-rank structures and numerical methods in matrix and tensor computations and their application”, National PI V. Simoncini
- PRIN2022, ‘IPIS- Inverse problems in the imaging sciences’, local PI, S. Morigi
- PRIN2022, “Statistical mechanics of Learning Machines”, Member, G. Sicuro

## Doctoral Position

### Computational Approaches in (Big) Data-driven Medical Modeling

## Doctoral Programme

Mathematics

### Description of the doctoral position's main topic

In the past few decades, large amount of data, including clinical records, medical images, genomic data and health behaviours, together with accurate data-driven modelling and simulations, have all concurred to the medical assessment of diagnosis, prognosis and therapy of pathologies. This project aims to design mathematically sound computational approaches for data analysis, mainly for clinical purposes, by making use and advancing state-of-the-art “Big data” and machine learning methodologies. Different research directions can be explored in which a massive and effective use of data via automated procedures is investigated.

### Sub-themes of the doctoral position's main topic (if any)

#### *Big Data in the Imaging Sciences*

Imaging sciences rely heavily on machine learning algorithms and mathematics for data analysis. However, these techniques face challenges related to the inherent ill-posedness of inverse problems in imaging. This project tackles these challenges by developing mathematical transdisciplinary skills for the imaging sciences. In the context of machine learning methodologies, a rigorous mathematical investigation of learning techniques is essential, especially when applied to signal/imaging inverse problems, in which the intrinsic ill-posedness of the model might cause unstable image reconstructions, or poor generalization properties. Computational techniques will be mainstreamed into an application stage devoted to several imaging modalities.

#### *Unveiling the Dynamics of Learning in Large Datasets.*

We will investigate the computational aspects of training neural networks on complex data. By analysing non-convex optimization landscapes, we aim to uncover insights into convergence behaviour and stability. Our primary objective is to incorporate geometric features into the algorithmic processing of large medical datasets. By doing so, we aim to enhance our understanding of how neural networks hierarchically recognize and process geometric patterns within medical data. Leveraging extensive medical image datasets, the project will contribute to the development of automated diagnostic software.

### *Energy saving algorithms for Biomedical Pattern Formation.*

Turing pattern formation refers to the process by which complex spatial patterns emerge from homogeneous initial conditions due to interactions between diffusible substances and its study is of cross-disciplinary interest including biological and medical modelling. Interactions over long time periods and in sufficiently large observation regions can lead to organized (Turing) patterns. These constraints lead to the need of massive and energy consuming computational resources, de facto limiting the modelling to small, simplified samples. We aim to develop and apply energy-aware algorithms that can drastically reduce computational resources and provide real time results in biological and epidemiology applications. The plan is to advance the use and understanding of memory saving state-of-the art methods in randomized computational linear algebra and clustering techniques, employing rapidly evolving standards of computer arithmetic formats for machine learning of big data.

### *Big data for a digital tool for Alzheimer's disease*

This project aims to develop a new and innovative digital tool for Alzheimer's disease (AD), based on a robust personalised mathematical model, to help assess AD progression and predict clinical outcomes in response to pharmacological treatment. The development of a customised and reliable digital tool for AD requires big data, to calibrate and validate the mathematical models using a large number of medical images, and to give the model robustness in predicting the AD state. Moreover, customisation of the model for personalised medicine requires big medical data to create individual brain networks. The use of a digital tool could provide a practical strategy to help AD patient care and decision-making processes in the healthcare system.

## Potential Supervisors

Germana Landi; Serena Morigi; Gabriele Sicuro; Valeria Simoncini; Maria Carla Tesi

## Doctoral candidate's desirable skills and competences

### ***Scientific and technical skills***

Background in data analysis, numerical mathematics and computational experience, and the preparation of mathematical models. All these skills can generally be acquired during a bachelor and master program in mathematical sciences and related fields.

## Description of the research group(s) in which the doctoral candidate will be integrated

Several permanent members of the Department of Mathematics are participating in the proposal, and among them are three members of the Faculty board of the PhD course in Mathematics.

The sub-themes topics are within the unique expertise of the PIs. During their career, the PIs have significantly contributed to the project's subjects, and their collaboration networks and publications show their leading profiles in the proposed topics.

Some of the topics of the project are also taught at the master level in our Mathematics program, and the PI have a high quality experience in teaching these topics.

Schools:

- Int.I Ph.D. Summer School: Mathematics and Machine Learning for Image Analysis, June 4-12 2024, ref. S. Morigi, at DiMAT, Bologna
- CIME-EMS Summer School: Exploiting Hidden Structure in Matrix Computations. Algorithms and Applications, June 21-26, 2015, ref. Simoncini

Workshops:

- “Sketching, Mixed Precision, and Associated Algorithms for Scientific Computing”, 18 -19 January 2024, dr. Palitta, at DiMAT, Bologna
- “Youth in High-Dimensions: Recent Progress in Machine Learning, High-Dimensional Statistics and Inference”, 29/05-02/06/23, SISSA

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The Department of Mathematics provides very high quality resources consisting of expertise, knowledge and advanced laboratories. In particular the Laboratory for High Performance Graphics and Vision Computing, equipped with 3D printer, High Performance workstations, as well as Virtual and Augmented Reality devices.

## Collaboration networks involving the research team

Principal investigators have several interdisciplinary collaborations, more specifically in the fields of medicine and data analysis (CINECA, Physics Dept and profit companies, as well as other Universities both national and international). This creates a well established scientific environment which is a fertile ground for international students.

Big Data in the Imaging Sciences: The project develops mathematical transdisciplinary skills for the imaging sciences and includes collaborations with: Giovanni Alberti (Università di Genova (I)); Samuli Siltanen (University of Helsinki, (FI)); Luca Calatroni (CNRS I3S laboratory, Sophia-Antipolis, (F))

Unveiling the Dynamics of Learning in Large Datasets: The project will benefit from a collaboration with a private entity, SynDiag srl, keen on the advancement of diagnostic software through artificial intelligence: such collaboration will facilitate the integration of real-world requirements, industry expertise, and practical considerations into the research project. The private entity's insights will also contribute to the refinement and applicability of the theoretical model. Finally, the group has an international network of active collaborations, including active ongoing projects with the Ecole Normale Supérieure of Paris and King's College London.

Energy saving algorithms for Biomedical Pattern Formation: The project will see the synergic collaboration of researchers with different background, working on the modelling, the numerical discretization and the HPC challenges, located at the Università del Salento (I), the EPFL Lousanne (CH), Chemnitz University (D) and other European Institutions.

Big data for a digital tool for Alzheimer's disease: Given the multidisciplinary nature of the project, the research will be carried out in collaboration with the following institutions, with expertise both in mathematics and neuroimaging:

Hospital del Mar Research Institute, Barcelona (ES); University Hospital of Lille (F); University of Oxford- Dept Physiology, Anatomy and Genetics, Oxford (UK); Dipartimento di Neuroscienze, Università di Torino (I); Lab. Mathématiques et Modélisation d'Évry, Dép. de Math., Uni d'Évry Val d'Essonne (F).

**International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year**

- PRIN2022, "IPIS- Inverse problems in the imaging sciences", local PI, S. Morigi
- PRIN2022, "Statistical mechanics of Learning Machines", Member, G. Sicuro
- Almaidea2022, "Modellazione matematica della malattia di Alzheimer: approcci numerici, analitici e con neuroimmagini", local PI: G. Landi
- PRIN2022, "Low-rank structures and numerical methods in matrix and tensor computations and their application", National PI V. Simoncini



## Doctoral Position

### **Big Data handling in Next-generation Particle and Astroparticle Physics Experiments**

## Doctoral Programme

Data Science and Computation

## Description of the doctoral position's main topic

The Particle Physics and Astroparticle Physics program has achieved major advancements in fundamental physics, technology, and design of innovative computational tools and algorithms, resulting in landmark discoveries like the first observation of the Higgs boson at CERN in 2012 and the first detection of gravitational waves by LIGO and Virgo in 2015/2016. Future challenges require innovative software and computing solutions towards the physics mission.

Using CERN as an example, computing operations are managed through the Worldwide LHC Computing Grid (WLCG) project, a global collaboration spanning 170 computing centres across 40 countries. WLCG aims to provide global computing resources for storing, distributing, and analysing approximately 200 PB of LHC data annually. The High-Luminosity LHC (HL-LHC) project, a top priority since 2013, is slated to start in 2029, significantly increasing collision rates and enabling potential discoveries. For instance, HL-LHC is projected to produce a minimum of 15 million Higgs bosons yearly.

Significant investments are being made in experimental communities to prepare for the upcoming challenge. This includes enhancing the data acquisition pipeline to handle a broader range of collision events, as proton-proton collisions produce a diverse array of particles at a rate of 40 MHz. These events are tracked by radiation-hardened detectors and processed through multi-step "trigger" systems designed to rapidly select or reject data. Data collection throughput is crucial for identifying potentially significant signatures with confidence, a necessity that will only grow with the advent of HL-LHC.

The project of work of a COFUND "Futuredata4EU" scholarship will focus on software and computing tools as enabling technologies for extraction of insight from Big Data, towards an increased capacity to trigger and record relevant data, hence facilitating the currently needed improvements to LHC data collection in Run-3, with the mindset to also look forward to future data collection needs, i.e. contribute to the following HL-LHC phases as well as providing critical insight to develop future detectors and data flows for even more ambitious objectives e.g. in the Future Circular Collider (FCC) and in the Einstein Telescope (ET) for gravitational waves detection, currently in their Feasibility Study phases.

Among the lines of work foreseen in this PhD project, the following can be mentioned:

- improve ML-assisted data collection (including simulations) and better leverage available (and new) computing infrastructures;
- develop data-driven, improved and accelerated algorithms and techniques (including AI-based) to filter out uninteresting events and filter in exotic interesting signatures at high speed and efficiency;
- contribute to the design and implementation of innovative AI-powered real-time processing workflow, with the ambitious goal to analyse every single collision produced in large-scale data-intensive experimental settings.

## Sub-themes of the doctoral position's main topic (if any)

None

## Potential Supervisors

Daniele Bonacorsi; Felice Pantaleo; Andrea Bocci

## Doctoral candidate's desirable skills and competences

### ***Scientific and technical skills***

- Familiarity with main concepts in experimental particle and/or astroparticle physics
- some experience in data acquisition and/or data analysis techniques
- programming skills, particularly in languages such as C++ and/or Python
- familiarity with statistical methods and machine learning frameworks
- ability to work effectively and independently in a collaborative research team
- excellent written and verbal communication skills.

### ***Other skills***

- previous involvement in large-scale experimental projects or collaborations
- advanced knowledge of experimental particle physics and/or astroparticle physics
- demonstrated experience with specific data handling tools and frameworks
- knowledge of distributed computing systems and parallel processing techniques
- familiarity with GPU programming and HPC systems

## Description of the research group(s) in which the doctoral candidate will be integrated

D. Bonacorsi is Full Professor in Experimental Physics at University of Bologna, working over the last 20 years on High Energy Physics (HEP) experiments at CERN. His research interests expanded to the design, deployment and operations of large-scale Software and Computing systems for data-intensive science. In the LHC community, he has been Offline and Computing coordinator for the CMS experiment at the LHC, he collaborates with major Data and Computing Centres in EU, US, Asia, and he has been among the pioneers of Machine/Deep Learning solutions in the HEP community. Dott. F. Pantaleo and Dott. A. Bocci are CERN

staff scientists, have been covering leading roles in the Trigger of the CMS experiment at LHC since more than a decade, and in the adoption of deep learning techniques in CERN experiments, and are now deeply involved in designing and developing advanced solutions for next-generation triggers in HEP. The research group is complemented at University of Bologna by Dr. Carlo Battilana and Prof. Alessandra Fanfani, who are researchers with advanced software skills and ability to work in large collaboration on physics analysis, trigger studies and computing activities, by Dr. Tommaso Diotallevi, currently a NRRP-funded (National Recovery and Resilience Plan) RTDa researcher involved in physics-serving technology advancements and computing infrastructures, and a set of PhD researchers enrolled in the “Physics” PhD and in the “Data Science and Computation” PhD at University of Bologna. All UniBO colleagues listed above have a standing affiliation with the Italian INFN funding agency for HEP research, and all senior colleagues listed above have a demonstrated records of mentoring Bachelor and Master students, as well as PhD and postdoc researchers. The selected PhD candidate will be based in Bologna, although frequent visits to CERN as well as extended period of secondment at CERN or in other collaborating institutions is foreseen throughout the duration of the PhD programme. The research group is committed to maintaining an open and collaborative work environment that stimulates professional and personal growth of all members, and to fostering a diverse and inclusive research environment that welcomes individuals of all genders and ethnicities.

### Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The PhD candidate will have access to the research facilities of the DIFA department, and - for computing needs - to local CPU and GPU farms, both experiment-specific and multi-experiment, including the resources dedicate to the future astro-particle Einstein Telescope project.

The PhD candidate will be considered for affiliation to a CERN experiment, hence becoming a CERN user, able to access the CERN research facilities.

The PhD candidate will be supported to have access to the computational resources offered by NRRP-funded (National Recovery and Resilience Plan) national initiatives such as the “National Centre for HPC, Big Data and Quantum Computing” and the “Future AI Research” (FAIR) partnership.

If required and relevant, the PhD candidate will be supported to prepare a dedicated ISCRA project with the CINECA supercomputing centre, located in the Bologna Technopole, to take advantage of the high-performance computing facilities of the Leonardo supercomputer.

The overall area of the Bologna Technopole will offer additional chances for interdisciplinary collaborations on advanced technology research around Big Data challenges with colleagues from a variety of diverse disciplines and on a vast set of topics and applications - ranging from weather forecast to smart mobility

solutions, from energy efficiency to hardware-oriented research, from digital twins to quantum computing research.

Finally, the Bologna Technopole will also offer a stimulating environment to be in contact with SMEs of the Emilia Romagna region, complementing the academic research with potential collaborations with industrial partners on topics of common interest, which will expand and fertilise the personal vision and professional skills of the PhD candidate.

### Collaboration networks involving the research team

The research team involving the FutureData4EU doctoral candidate is deeply embedded within extensive research collaboration networks, providing substantial added value to candidates. These networks span across academia and international research institutions, computing centres and data centres in Europe, US and Asia, in the network created by the World-wide LHC Computing Grid, fostering a rich environment for research collaborations and knowledge sharing. Within academia, in particular, our team collaborates closely with renowned universities and research institutes worldwide, offering candidates opportunities for collaborative research, joint publications, and access to diverse expertise. This academic collaboration network facilitates exposure to cutting-edge research methodologies and enables candidates to engage with leading scholars in the field. Furthermore, strong ties in the Bologna Technopole with industry partners ensure that candidates gain practical insights into real-world applications of data science and Big Data challenges and solutions.

Overall, the collaboration networks involving our research team will provide the FutureData4EU doctoral candidates with a unique and enriching research experience, as candidates will have the opportunity to leverage these networks to expand their knowledge, develop valuable skills, and make meaningful contributions to the field on both a local and global scale.

### International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

Internationally, the PhD candidate will be connected to large-scale CERN experiments and all related EU/US/national projects.

Nationally, the PhD candidate will be connected to NRRP-funded (National Recovery and Resilience Plan) initiatives, namely:

- “National Centre for HPC, Big Data and Quantum Computing”, Mission 4, “Istruzione e Ricerca”, Component 2, Investment 1.4, funded by the European Union - NextGenerationEU with an overall budget of about 320 MEuros, steered by the ICSC Foundation, whose President is Prof. Antonio Zoccoli (also INFN President and Full Professor at the University of Bologna)

- “Future AI Research” (FAIR) partnership, Mission 4, “Istruzione e Ricerca”, Component 2, Investment 1.3, funded by the European Union - NextGenerationEU, with an overall budget of about 115 MEuros, which has WP whose activities are based in Bologna, with Prof. Michela Milano (Full Professor at the University of Bologna) as PI.

## Doctoral Position

### **Neuro-symbolic artificial intelligence for big data**

## Doctoral Programme

Engineering science

## Description of the doctoral position's main topic

The analysis of Big Data poses several challenges: on one side, the variety of data (tables, time series, knowledge graphs, natural language texts, sound, images, videos) requires technologies able to extract information from different modalities, on the other side, the volume of data involves the adoption of smart approaches with high scalability. Moreover, the aim of the analysis also plays a relevant role, going from the simple prediction of a continuous or discrete dependent variable to tasks requiring advanced reasoning such as the identification of solutions to complex problems or the generation of novel data, also in different modalities. Finally, the system performing the analysis should be trustworthy, protecting the users' privacy, avoiding discrimination, providing explanations for its decision, being robust, and fostering sustainability.

To this purpose, Artificial Intelligence (AI) seems an excellent candidate for extracting information from Big Data and for the generation of new data. The recent successes of Deep Learning (DL) and Large Language Models (LLM) provide versatile tools that complement the strong achievements of classical, symbolic AI, such as Machine Learning (ML), reasoning, Constraint Programming (CP), probabilistic inference, planning and multi-agent systems.

Each of these technologies has strengths and weaknesses: to exploit the strengths and curb the weaknesses, it is necessary to design advanced approaches for combining different techniques.

The topic of the doctoral research will thus be the composition of modern AI with classical AI to obtain systems able to analyse multimodal, diverse, big, and noisy data in a way that is transparent, fair, robust, and sustainable. This involves the combination of sub-symbolic techniques, such as DL and LLM, with symbolic techniques, such as logic, probabilistic graphical models, CP and planning, leading to the development of the field of Neuro-Symbolic Artificial Intelligence (NeSy).

NeSy will be inspired by the ways the human brain forms thoughts, as argued in [1]: a cooperation of two systems, System 1 and System 2, where the first is fast, automatic, unconscious, while the latter is slow, effortful, logical, conscious. System 1 is used to generate approximate answers quickly, only to engage System 2 when refining the answers is necessary.

Recently, NeSy has been the subject of much attention [2], with various successful approaches for example integrating DL with logical reasoning, but much needs to be done to fully achieve an integration that can analyze data in various modalities and solve complex tasks.

This doctoral project will put the candidate at the forefront of research in AI, opening up ample employment opportunities both in academia and in industry.

[1] Kahneman, Daniel (2011). Thinking, Fast and Slow

[2] Sarker, Md Kamruzzaman; Zhou, Lu; Eberhart, Aaron; Hitzler, Pascal (2021). "Neuro-symbolic artificial intelligence: Current trends". AI Communications. 34 (3): 197–209

### Sub-themes of the doctoral position's main topic (if any)

Sub-theme 1: Combining LLM with probabilistic logic reasoning: exploiting LLM to extract a symbolic representation of a multimedia input that should then be processed by a probabilistic logic system. The challenge is how to train the system end-to-end.

Sub-theme 2: Analyzing large knowledge graphs: learning interpretable and accurate models from knowledge graphs of significant size, to perform completion and triple classification.

### Potential Supervisors

Fabrizio Riguzzi; Marco Gavanelli; Evelina Lamma

### Doctoral candidate's desirable skills and competences

The candidate should have basic knowledge of:

- Symbolic ML
- Deep Learning
- Symbolic reasoning
- Probability theory
- Probabilistic graphical models

### Description of the research group(s) in which the doctoral candidate will be integrated

The AI@UNIFE group of the University of Ferrara (<https://ai.unife.it>) has a track record of research in AI, focusing on Statistical Relational Artificial Intelligence (StarAI), Deep Learning and Constraint Programming. We have developed the StarAI systems: - cplint, that can be tried online at <https://cplint.eu> - TRILL, that can be tried online at <https://trill-sw.eu> - BUNDLE, that can be tried online at <https://bundle.ml.unife.it> - Belief propagation demo, <https://ml.unife.it/belief-propagation/>. Some of the most relevant publications are: - Damiano Azzolini, Fabrizio Riguzzi, and Evelina Lamma. A semantics for hybrid probabilistic logic programs with function symbols. Artificial Intelligence, 294:103452, 2021. - Michele Fraccaroli, Evelina Lamma, and

Fabrizio Riguzzi. Symbolic DNN-Tuner. Machine Learning, 2021 - Bertagnon, Alessandro, and Marco Gavaneli. "Improved filtering for the Euclidean traveling salesperson problem in CLP (FD)." Proceedings of the AAAI Conference on Artificial Intelligence. Vol. 34. No. 02. 2020. - Tom Schrijvers, Birthe Van Den Berg, and Fabrizio Riguzzi. Automatic differentiation in prolog. Theory and Practice of Logic Programming, 23(4):900–917, 2023  
Elena Bellodi, Marco Alberti, Fabrizio Riguzzi, and Riccardo Zese. MAP inference for probabilistic logic programming. Theory and Practice of Logic Programming, 20(5):641--655, 2020 - Arnaud Nguembang Fadja and Fabrizio Riguzzi. Lifted discriminative learning of probabilistic logic programs. Machine Learning, 108(7):1111--1135, 2019 - Fabrizio Riguzzi, Elena Bellodi, Riccardo Zese, Giuseppe Cota, and Evelina Lamma. A survey of lifted inference approaches for probabilistic logic programming under the distribution semantics. International Journal of Approximate Reasoning, 80(Supplement C):313--333, January 2017 - Riguzzi, F., Bellodi, E., Lamma, E., & Zese, R. (2015, July). Reasoning with Probabilistic Ontologies. In IJCAI (pp. 4310-4316).

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The University of Ferrara hosts the Copernico HPC machine with 3 nodes and 3 Nvidia H100 GPUs. During 2024, it will be enlarged with another node with 4 Nvidia L40S GPUs. The doctoral candidate will have access to Copernico and to Leonardo (<https://leonardo-supercomputer.cineca.eu>), the supercomputer hosted by Cineca, with 3456 computing nodes, each equipped with four NVidia A100 SXM6 64GB GPU, capable of nearly 250 PFlops and equipped with over 100 PB of storage capacity.

## Collaboration networks involving the research team

AI@UNIFE cooperates with many leading researchers including:

- Prof Tom Schrijvers, KU Leuven, Belgium
- Prof. Brian Jalaian, University of West Florida, USA
- Prof. Vitor Santos Costa, Universidade do Porto, Portugal
- Prof. Antonis Kakas, University of Cyprus, Cyprus- Prof. Luís Moniz Pereira, Universidade Nova de Lisboa, Portugal
- Dr. Jan Wielemaker, SWI-Prolog Solutions b.v
- Dr. Theresa Swift, Johns Hopkins University



International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

“Advanced Integrated machine Learning (AIR)”, national project financed by Piano Nazionale di Ripresa e Resilienza (PNRR), cascade project of “Future Artificial Intelligence (FAIR)” – Spoke 8, PI Elena Bellodi. AI@UNIFE is the sole recipient of the funding.

“Support System for Sustainable Smart Cities (S4C)”, regional project financed by PR-FESR EMILIA ROMAGNA 2021-2027, PI Elena Bellodi. AI@UNIFE is involved as a whole in the project.

“Foundations of Trustworthy AI - Integrating Reasoning, Learning and Optimization (TAILOR)”, a Research and Innovation Action submitted to the Horizon 2020 call ICT-48-2020 (call identifier H2020-ICT-2018-20). TAILOR is one of the four Networks of Excellence envisioned in ICT-48-2020. AI@UNIFE participates as a member of CINI, partner of the project.

“Sviluppo di un’intelligenza artificiale per favorire la sostenibilità della spesa corrente delle famiglie e l’affidabilità dei crediti (MIRC.0)” funded by the Italian Ministry for Economic Development. The project is lead by the company Fire S.a.s. and aims at developing a decision support system for supporting the activity of debt collection of the company. AI@UNIFE participates as partner

## Doctoral Position

### **Methodologies and technologies of data science and data analytics: beyond the analytics of high energy physics big data**

## Doctoral Programme

Physics

### Description of the doctoral position's main topic

The analysis and management of extensive data volumes has a pivotal role in fundamental research, industrial applications, medicine, social sciences, meteorology, engineering, and many more disciplinary fields. The huge amount of data produced by experiments at the LHC accelerator at CERN, or the simulation of billions of particles interacting with a detector are basic examples of computationally complex problems that need to be solved with HPC and HTC. This project aims to investigate applications of high-performance heterogeneous computing (CPU/GPU) in the field of fundamental physics, as use cases for acquiring skills in developing novel computation methods for big data analysis on these architectures.

In the LHCb experiment at CERN, for example, data processing and Monte-Carlo simulation production is handled through a massive infrastructure of distributed computing in several tiers around the world which operate CPU farms in parallel. The Ferrara group is involved in analysis for which computationally expensive, multidimensional amplitude analysis of decays are necessary in order to investigate for unexpected contribution beyond the Standard Model of particle physics. Furthermore, the procedure of selecting signal events is often carried out by means of multivariate algorithms able to classify the signal and background species through supervised machine learning. The Ferrara group is also involved in the operation of the Ring-Imaging Cherenkov detectors for the experiment LHCb. The simulation of Cherenkov processes is another example of a computationally expensive algorithm, which needs to generate hundreds of photons per single charged particle and propagate each one of them through the volumes of the detector, simulating their path, reflections and interactions with the different materials. This is a problem which can be structurally parallelised and the best solution would be to run this part of the simulation on GPUs, which run independent parallel tasks.

Another case study on which these methods can be developed is the optimization and validation of the simulation, reconstruction, and analysis of a large experimental apparatus (DUNE - Deep Underground Neutrino Experiment, at FNAL) for neutrino physics on heterogeneous HPC architectures.

The reconstruction of neutrino interactions in the detectors of the DUNE experiment, for example, requires the combination of traditional CPU-based reconstruction algorithms with an innovative GPU-accelerated image reconstruction technique.

The successful candidate will work in a large collaboration, in a highly international environment, to be trained in the use of typical methodologies and technologies of data science and data analytics, focusing on HPC and HTC, and supervised machine learning for pattern recognition.

The purpose of the project is to train a young researcher capable of applying the acquired skills outside the academic world to achieve a true digital transition of society and the country.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Eleonora Luppi, Luca Tomassetti, Roberto Calabrese, Sebastiano Fabio Schifano

### Doctoral candidate's desirable skills and competences

Candidates for big data analytics need a multifaceted skill set tailored to navigate the complexities of massive datasets and extract valuable insights. Proficiency in programming languages is very useful, enabling them to manipulate data efficiently and develop custom analytical solutions. Strong physics, mathematical and statistical abilities permit them to apply advanced algorithms.

Moreover, the possess of critical thinking and problem-solving skills is very important, enabling them to identify patterns, trends, and anomalies within complex datasets, thereby driving informed decision-making and strategic planning.

Adaptability and a continuous learning mindset are paramount, given the rapid evolution of big data technologies and methodologies.

### Description of the research group(s) in which the doctoral candidate will be integrated

The research group pioneers the exploration of particle collisions and high-energy phenomena, of neutrino behaviour through cutting-edge data analysis techniques. Navigating through immense datasets generated by particle accelerators, we aim to unravel the properties matter and anti-matter and of neutrinos and their role in shaping the universe. Led by a team of dedicated scientists, we employ advanced statistical methods, machine learning algorithms, and computational models to extract meaningful insights from exabytes of raw data. Collaborating closely with international partners and leveraging state-of-the-art computing resources, our research aims to uncover fundamental particles and explore the nature of dark matter and dark energy. Moreover, our methodologies transcend disciplinary boundaries, finding applications in fields ranging from

environmental monitoring to financial analysis, underscoring the versatility and impact of particle physics big data analytics beyond the boundaries of scientific inquiry. Our developments hold the potential to revolutionize technologies and advance scientific frontiers, making a profound impact on society. The researchers actively engage in particle physics experiments, including those conducted at well-known facilities such as CERN, with the LHCb experiment, and Fermilab, with the DUNE experiment, as well as collaborative projects like the ICSC supercomputing centre for HPC, Big Data and Quantum computing. These endeavors are dedicated to advancing the technological frontier in data analytics for handling vast amounts of big data. In the last five years the researchers involved in the group have published more than 250 articles in International journal. Web page of the supercomputing ICSC centre: <https://www.supercomputing-icsc.it/en/icsc-home/> Web page of the Ferrara LHCb experiment group: <https://www.fe.infn.it/lhcb> Web page of the LHCb experiment: <https://lhcb.web.cern.ch/> Web page of the DUNE experiment: <https://www.dunescience.org/> Web page of the Ferrara DUNE experiment group: <https://www.fe.infn.it/index.php/it/attivita-e-ricerca/fisica-astroparticellare-e-del-neutrino?view=article&id=485&catid=16>

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The candidate will have access to all the laboratories of our Department needed for her/his research work, to the computing infrastructures, including COKA, the computing cluster “Computing On Kepler Architectures” funded by the University of Ferrara with the support of INFN, and the ICSC supercomputing centre facilities. If involved in one of the international experiments, she/he will access all the research infrastructures, available to the collaboration members, of the international laboratory where the experiment runs.

## Collaboration networks involving the research team

- ICSC - High-Performance Computing, Big Data e Quantum Computing Research Centre (51 Italian Institutions)
- DUNE - Deep Underground Neutrino Experiment. International consortium (over 200 institutions in over 30 countries, plus CERN).
- LHCb - Large Hadron Collider beauty experiment, International collaboration (86 different universities and laboratories from 18 countries)

All of these networks play integral roles in big data analytics, high-performance computing, and high-throughput computing, both in terms of their utilization and application for scientific outcomes. Moreover, they contribute significantly to the advancement of novel technologies and methodologies, aimed at further enhancing the technological frontier in data analytics.

Candidates for big data analytics need a multifaceted skill set tailored to navigate the complexities of massive datasets and extract valuable insights. Proficiency in programming languages is very useful, enabling them to manipulate data efficiently and develop custom analytical solutions. Strong physics, mathematical and statistical abilities permit them to apply advanced algorithms.

Moreover, the possess of critical thinking and problem-solving skills is very important, enabling them to identify patterns, trends, and anomalies within complex datasets, thereby driving informed decision-making and strategic planning.

Adaptability and a continuous learning mindset are paramount, given the rapid evolution of big data technologies and methodologies.

**International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year**

The main projects, relevant for Futuredata4EU, in which the members of the team have been involved in the last 5 years are (in synthesis):

- ICSC - High-Performance Computing, Big Data e Quantum Computing Research Centre. National public call for the presentation of proposals for the strengthening of research structures and the creation of R&D "national champions" on some Key Enabling Technologies to be financed within the National Recovery and Resilience Plan. D. D. n.3138,16-12-2021. Spoke 1: UNIFE responsible: F. Schifano, members: L. Tomassetti, M. Guarise; Spoke 2: UNIFE responsible: E. Luppi, members: R. Calabrese, M. Guarise, L. Capriotti; Spoke 10; member: C. Bozzi
- DUNE - Deep Underground Neutrino Experiment. International collaboration (funded, in Italy, by INFN). since 2020. Ferrara responsible: L. Tomassetti; members: E. Luppi, R. Calabrese, S.F. Schifano, M. Guarise
- LHCb-run3 - Large Hadron Collider beauty. (funded: in Italy, by INFN) run3 since 2022, members: R. Calabrese, E. Luppi, L. Tomassetti, C. Bozzi, L. Capriotti, M. Guarise
- Phydex Para-hydrogen and diatomic molecules for EDM studies – national project (funded by INFN); since 2022, Ferrara responsible M. Guarise, members: R. Calabrese, L. Tomassetti.

## Doctoral Position

### **Data-driven modeling of brain circuits for advanced digital twins**

## Doctoral Programme

Neuroscience

## Description of the doctoral position's main topic

There is large consensus on the needs for strategies encompassing digital solutions in the field of biomedical research and more in general in health. The increasingly large amount of data generated through experimental methods is driving the development of data-driven methods to reproduce neuronal circuit functions; for instance, digital TWINS of neurons and circuits are becoming effective tools to predict the dynamics of variables inaccessible to experiments. Such tools can allow to explore physiological and pathological circuit mechanisms providing the possibility to test pharmacological and therapeutic solutions to neurological diseases. This topic is focused on advancing research in the field of neurodegenerative diseases, performing screening of pharmacological compounds, and assessing innovative strategies for therapeutic and/or surgical intervention. The idea is to create data-driven single cell resolved models of brain structures. The models will describe neuronal and synaptic elements with different levels of detail: from ionic channels to population dynamics providing the possibility to observe and understand single neurons dynamics and their role within large networks. By developing informatic tools allowing to investigate different scales from micro- to meso- and macroscale, models will serve as templates for the generation of digital copies of human brain structures. In longer-term perspectives, the outcomes will allow to create digital twins for predictive medicine. The doctoral research will be well inserted into two large initiatives at the national (EBRAINS-Italy) and international level (EBRAINS). In both cases the focus is on digital research infrastructure for brains research. The researcher will be therefore exposed to a dynamic and international research environment with several possibilities of interactions with the laboratories of the network.

More specifically, the development of large-scale neuronal circuits is conducted in close collaboration with the group of Michele Migliore at the Biophysics Institute of the CNR in Palermo. Dr Migliore is also coordinating the EBRAINS-Italy initiative which has been funded by the Italian Minister of University and Research with 22 M Euros and encompasses 17 research institutions. Moreover, under the framework of EBRAINS “the European brain research infrastructure”, the collaboration with the group of Viktor Jirsa (Univ of Marseille) resulted in the integration of the first data-driven model of the human hippocampus within whole brain simulator “the virtual brain”. The extended network of national and international collaborations will allow the researcher to evaluate a wide series of career opportunities in the field of research. Finally, the

process of the digitalization of biomedical research is involving companies (pharma companies among all). The researcher will have career opportunities also in this field, where at least three different companies have shown interest.

### Sub-themes of the doctoral position's main topic (if any)

None

### Potential Supervisors

Jonathan Mapelli; Daniela Gandolfi; Michele Giugliano

### Doctoral candidate's desirable skills and competences

The candidate should have basic knowledge of programming in python and Matlab environment and a basic knowledge of computational neuroscience.

### Description of the research group(s) in which the doctoral candidate will be integrated

The Neuromorphic Intelligence Laboratory (NILAB - <https://www.nilab.unimore.it/>) of the University of Modena and Reggio Emilia is an interdisciplinary laboratory in which researchers coming several disciplines such as Physics, Engineering, Biology, Medicine investigates the mechanisms underlying the interactions between brain and environment. The final aim of the research is to reproduce in software and hardware the functions of human intelligence. Computational models reproducing brain circuits are generated starting from experimental data collected by means of biophotonics and electrophysiological tools and eventually converted into neuromorphic devices through the close collaboration with the group of electronic engineers of the Department of Engineering "Enzo Ferrari". The NILAB has two main units: experimental and computational. - The experimental unit has 1 temporary Assistant Professor (RTD-A) and two-PhD students, and two undergrad students working on the morphological reconstruction of human and murine brain tissues. Furthermore, electrophysiological recordings to reconstruct network activity of extended neuronal circuits are performed through a MultiElectrode Array platform and patch-clamp recordings. - The Neurocomputational unit has 1 Tenure Track Assistant Professor (RTT), 2 PhD students, 2 post-docs and 2 undergrad students working on the development, implementation and analysis of large-scale neuronal circuits. In particular the activity is focused on the hippocampus and on the application of hippocampal models in real tasks like spatial navigation. The group has recently published the first complete model of the scaffold of the CA1 of human hippocampus starting from the analysis of histological human brain images (Gandolfi et al 2023; <https://www.nature.com/articles/s43588-023-00417-2>). Similarly, a model of a cerebellar microcircuit has been developed and employed to analyze and predict the effects of a general anesthetics exploit this method as a digital tool for predictive medicine (Mapelli et al 2021; <https://doi.org/10.1038/s41598-021-83714-y>).

## Existing facilities that will be accessible and available to the doctoral candidate to conduct her/his research

The doctoral candidate will have access to computer, laptops and all the equipment of the laboratory including a dedicated data storage server. Furthermore, the doctorate will have access to the UNIMORE facility for computing and will be included within national and international projects giving access to large scale servers such as Leonardo on CINECA or Piz-Daint on CSCS server in Zurich.

## Collaboration networks involving the research team

The research group is involved in the EBRAINS-Italy network, an infrastructure for brain research involving 17 research institutions and collaborating to provide solutions, facilities and data for research on nervous system. At the international level the group is also included within EBRAINS Europe with the aim of providing a research service at the European level. Furthermore, the group is also involved in a bilateral collaboration between India and Italy to investigate brain functions through multiscale approaches.

## International and/or national and/or regional projects in which the research team is currently involved or has accessed through competitive calls, activated within the last 5 years, or set to start within 1 year

- EBRAINS-Italy; PNRR-IR funded by Italian Minister of University and Research (2022-2025); PI Michele Migliore (CNR-Palermo); Jonathan Mapelli Unit coordinator (UNIMORE) and task leader; Daniela Gandolfi, Giulia Maria Boiani and Anna Maria Costa are involved as participants. HIPPOCOMP; PRIN 2022 funded by Italian Minister of University and Research (2023-2025); PI Jonathan Mapelli; Daniela Gandolfi participant.
- MSBFIINE; bilateral collaboration project between INDIA and ITALIA funded by the Italian Minister of foreign affairs (2022-2025); PI (Giovanni Naldi, University of Milano); Jonathan Mapelli Unit coordinator (UNIMORE); Daniela Gandolfi task leader.
- SMART-BRAIN; ERANET- FLAGERA The Human Brain Project partnership JTC 2019 (2020;2023); PI Jonathan Mapelli; Daniela Gandolfi participant.
- Borsa di ricerca per metodi avanzati per la riduzione della sperimentazione animale: funded by Regione Emilia-Romagna (2022-2023).
- PhD funded by Regione Emilia Romagna (2023-2026) for green economy.